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materials & energy from refuse

October 7, 2016

The 2016 Bi--annual Meeting of the Global WTERT Council
Columbia University, NEW YORK CITY

Waste Management Research in Italy

Prof. Stefano Consonni
Dept. of Energy - Politecnico di Milano
MatER Study Center

The MatER Study Center

❖ Established at the end of 2010

❖ **Location:** LEAP (Energy and Environment Laboratory Piacenza), PIACENZA, Italy

MISSION: Establishing scientific bases for the many issues related to recovery from waste

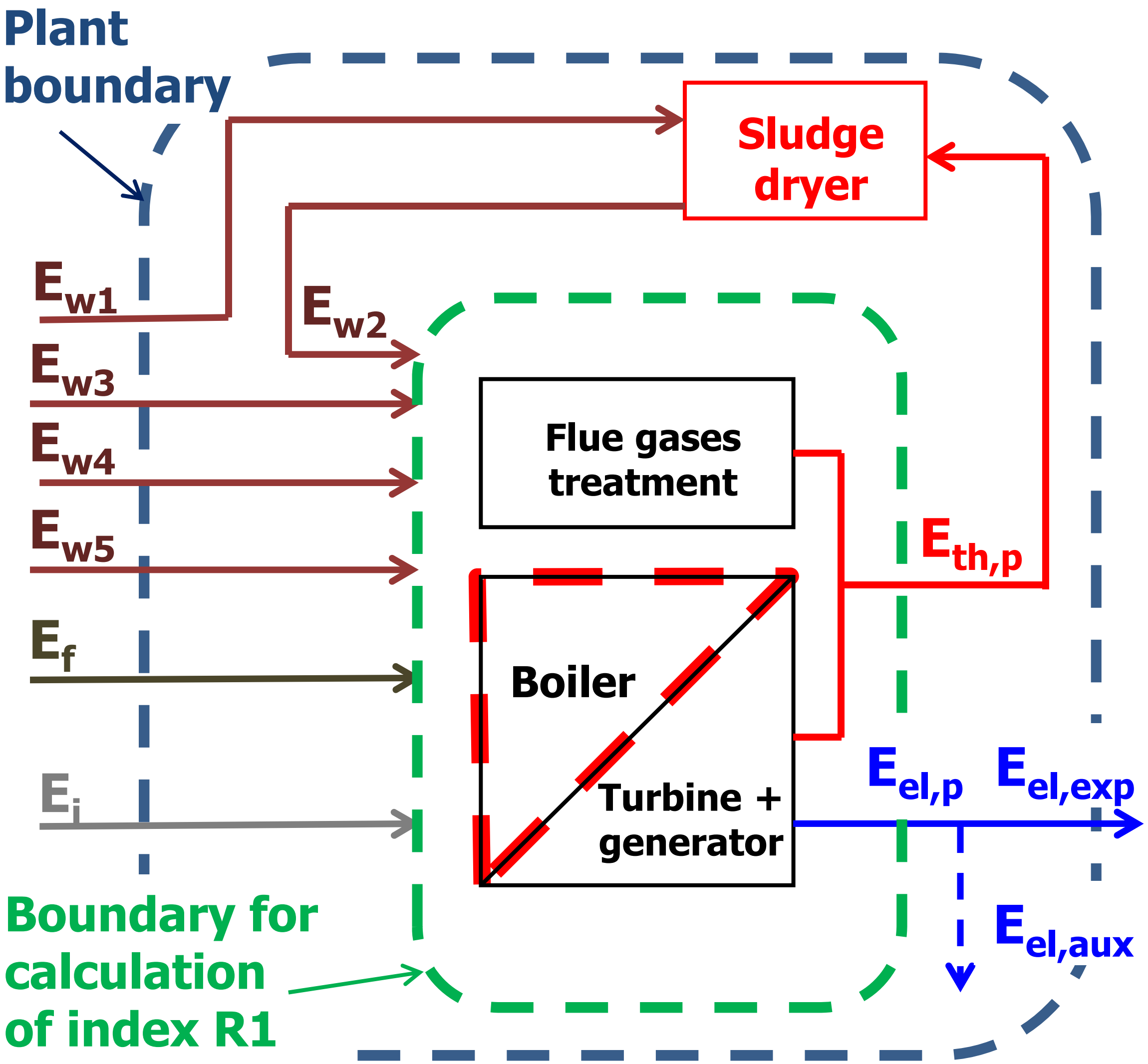
Main goal:

Give a rigorous scientific definition of the technologies and the policies which can be adopted for material and energy recovery, contributing to identify the most effective options for **sustainable, economically viable waste management practices**.

Member of the **Global WTERT Council (GWC)**

MatER partners

Calculation of the "R1" energy efficiency index



$$R1 = \frac{E_p - (E_f + E_i)}{0,97 \cdot (E_w + E_f)}$$

E_p = gross energy production
E_f = energy from fossil fuels
E_i = energy imported
E_w = energy input of waste

Major Issues

- System boundaries to be considered to evaluate E_w
- Quantification of all streams crossing the boundaries
- Averages over one whole year of operation
- Heat loss method (EN 12952-15)

Enviromental Evaluation of CDW management in Lombardy Region

- Quantify amounts and flows of Construction & Demolition Waste (CDW) managed in Lombardy Region
- Investigate types, amount, quality, actual use of "secondary products" from CDW
- Assess environmental performance of regional system by LCA methodology
- Identify benefits and critical aspects of the CDW recycling chain
- Define possible improving actions based on state-of-the-art recovery technology and LCA results

RECEIVED WASTE | **PLANTS** | **RECYCLED PRODUCTS**

Recovery of bottom ash from WTE plants

<u>Assessment of state-of-the art of</u>:

- processing technologies
- sustainability
- recovery of metals and of inert fraction

<u>Comparative evaluation of dry extraction vs. wet extraction</u>

- ferrous and non-ferrous metals recovery yield
- possible utilisation of inert fraction

About 1 Mton per year of bottom ashes are produced in Italy
(15%-25% in weight of incinerated waste)

Mineral fraction (≈90%)

Ferrous metals (7-15%)

Non ferrous metals (1-2%)

Materials from the recycling of packaging waste: quality and market

Materials from the recycling of packaging waste → Secondary materials

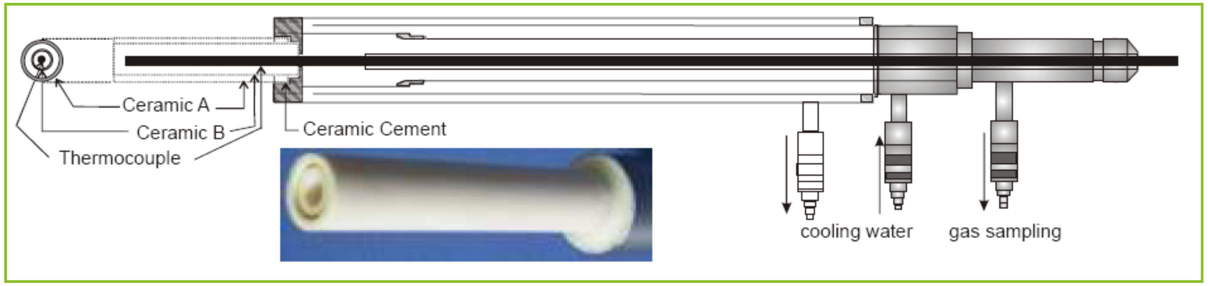
Quality and market of secondary materials → evaluation of benefits associated with their recycle

→ increase reliability of Life Cycle Assessment (LCA) studies
→ support decision tools in the choice of waste technologies and treatments
→ sustainable use of resources - close the loop
→ LCA and circular economy

Major Issues:

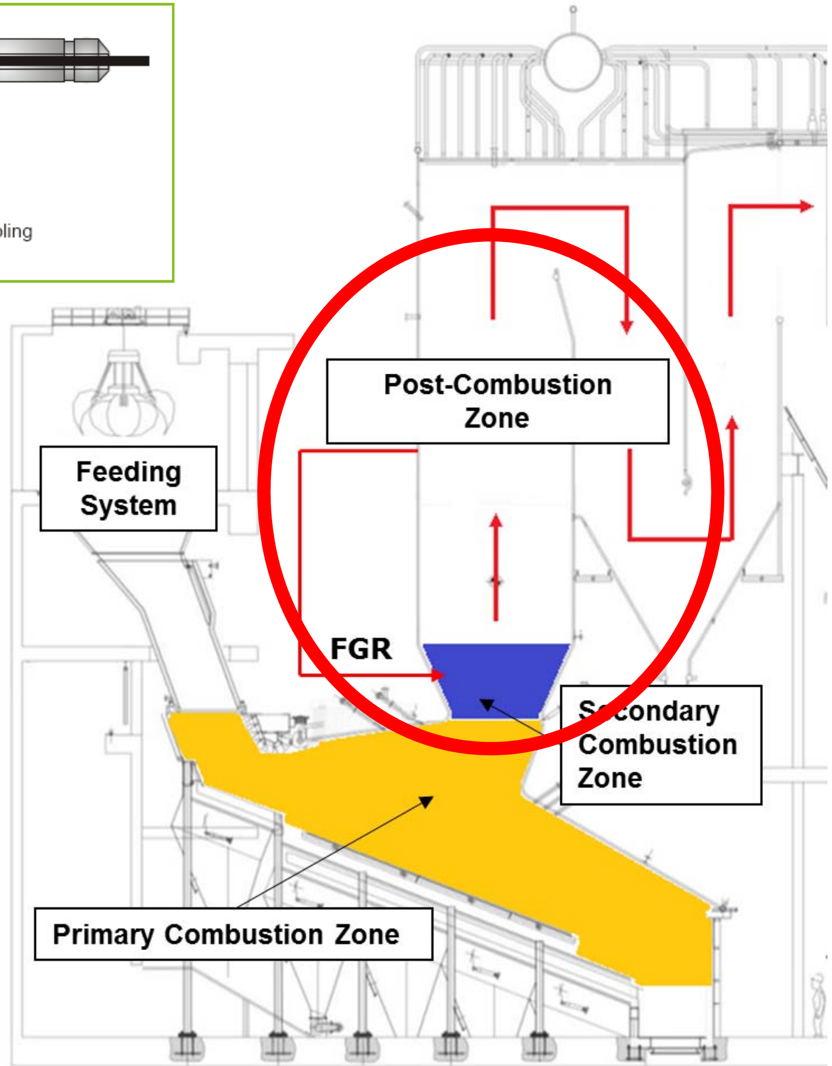
- Is the secondary material really a product or is it a waste ?
- If it is a product, what is the secondary material used for ? Is it used in substitution of other materials ?
- What is the origin of the substituted material ?
- What is the quality of the secondary material compared to the quality of the substituted material ?

High-Temperature measurements in post-combustion zone of WtE plants

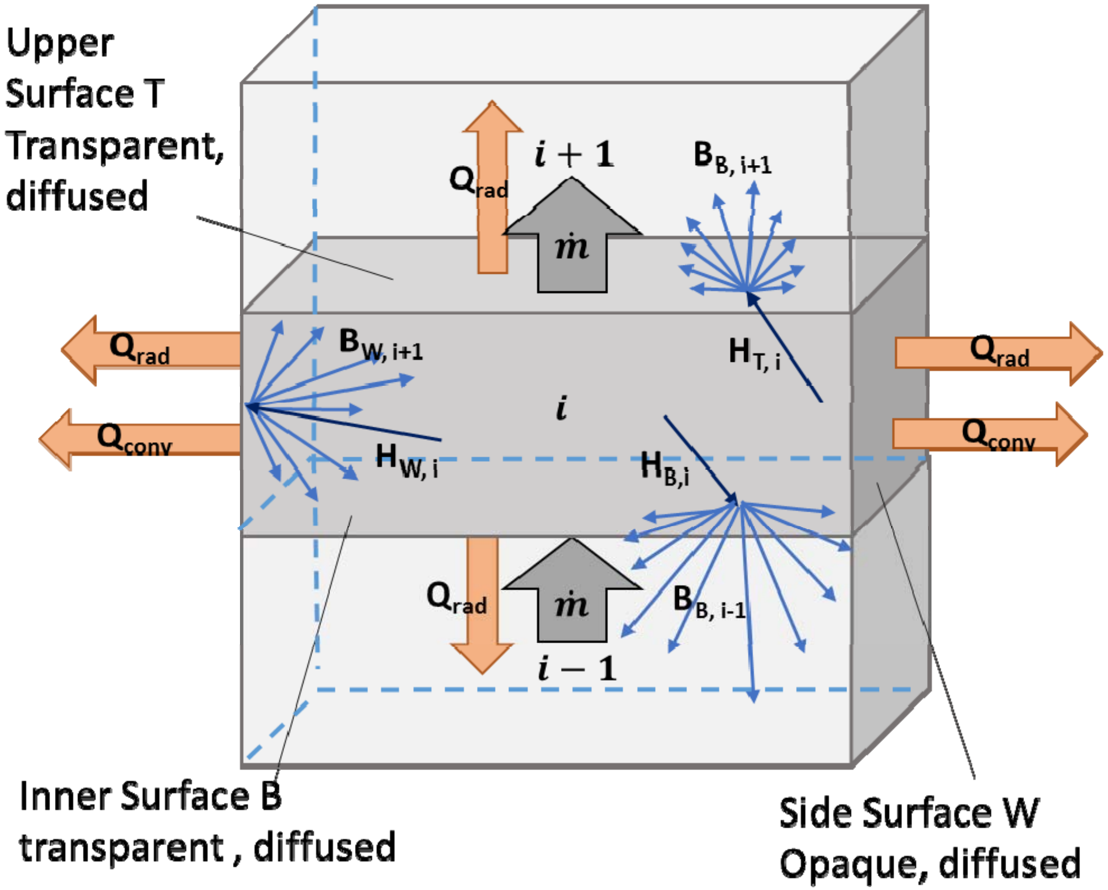


VDI-type suction pyrometers

- Design according to VDI/VDE 3511 part.5
- 2 coaxial ceramic shields
- 4 m useful insertion length
- 40 mm maximum outer diameter
- Titanium alloy
- Max working temperature with an S-type thermocouple: 1600 °C
- Max working temperature with a K-type thermocouple: 1200 °C
- Thermocouple with an Inconel 600 sheath of 3-3.5 mm outer diameter

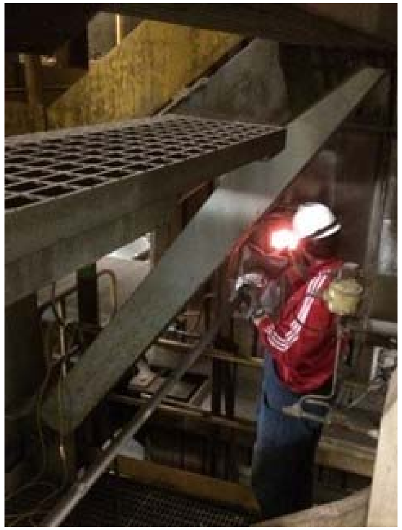
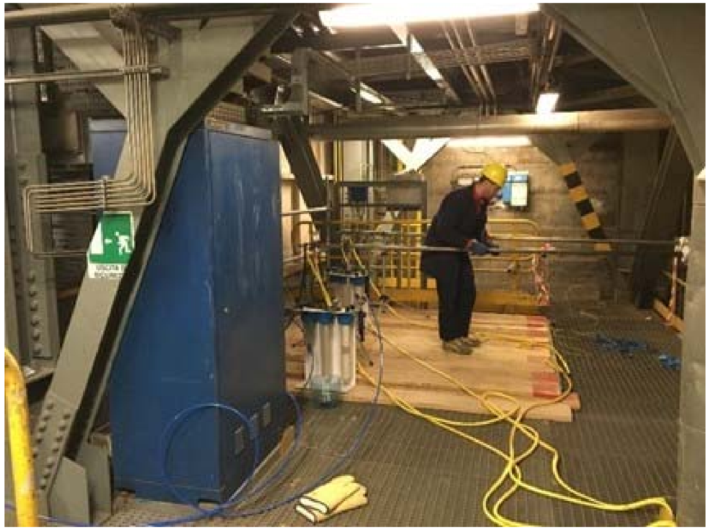


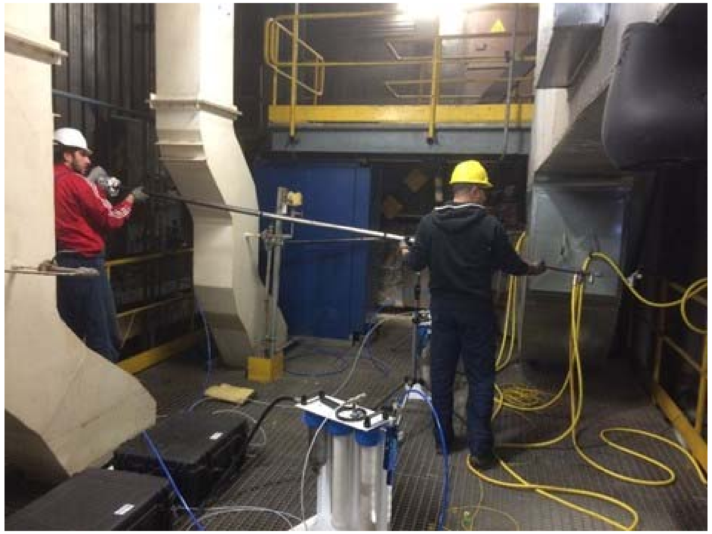
Modelling the post-combustion zone



- Simple 1-D zone model
- Neglect interactions among non-adjacent elements (coarse mesh)
- Gas and fly ash are assumed gray, with radiation properties according to VDI Heat Atlas
- Gas side fouling estimated by calibration against design and process data of a real WtE boiler
- Walls are assumed to behave as black bodies
- Temperature of water / steam in tubes is assumed constant (= evaporation temperature)
- Fully refractory-lined walls

Setting up the equipment for high-T measurements

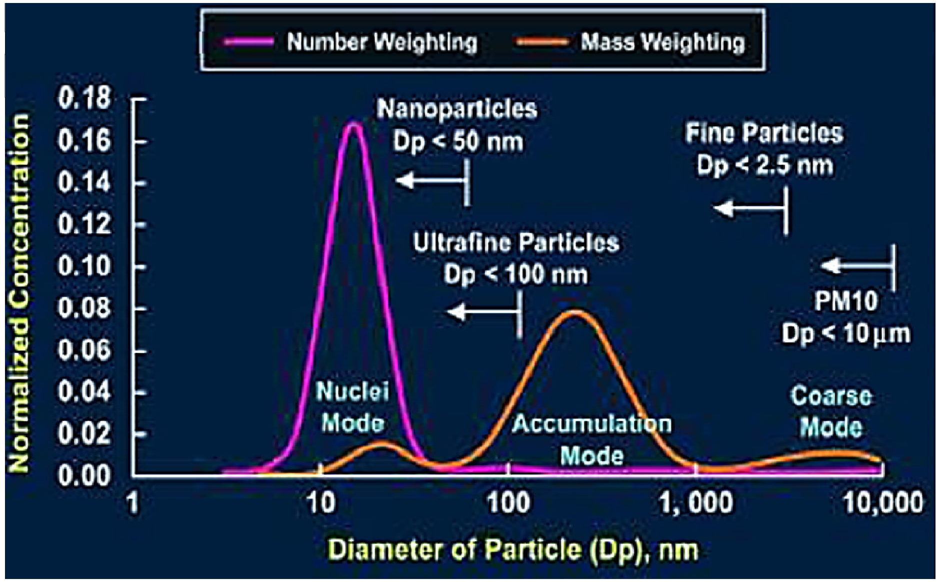




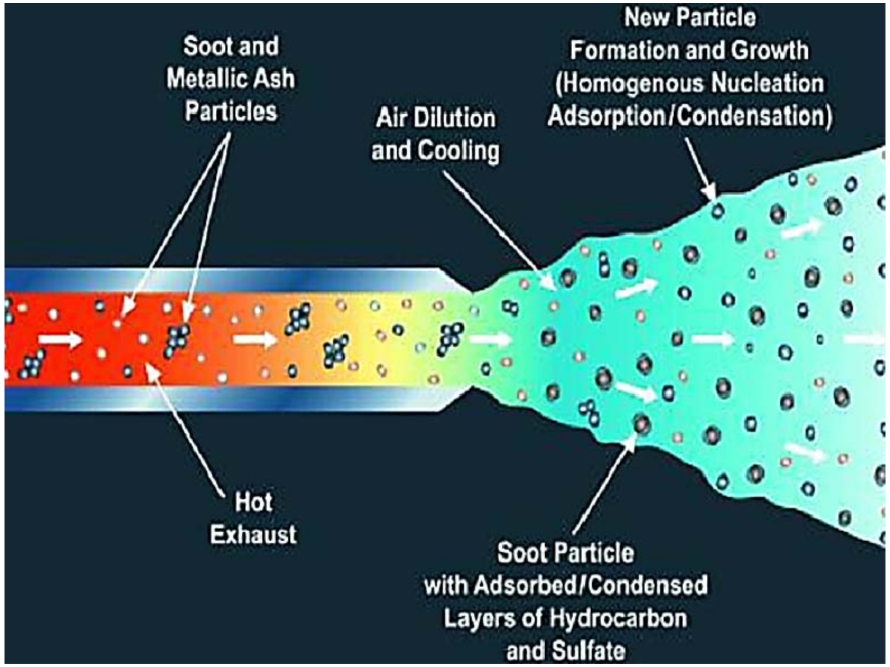


Measurements on stationary combustion plants

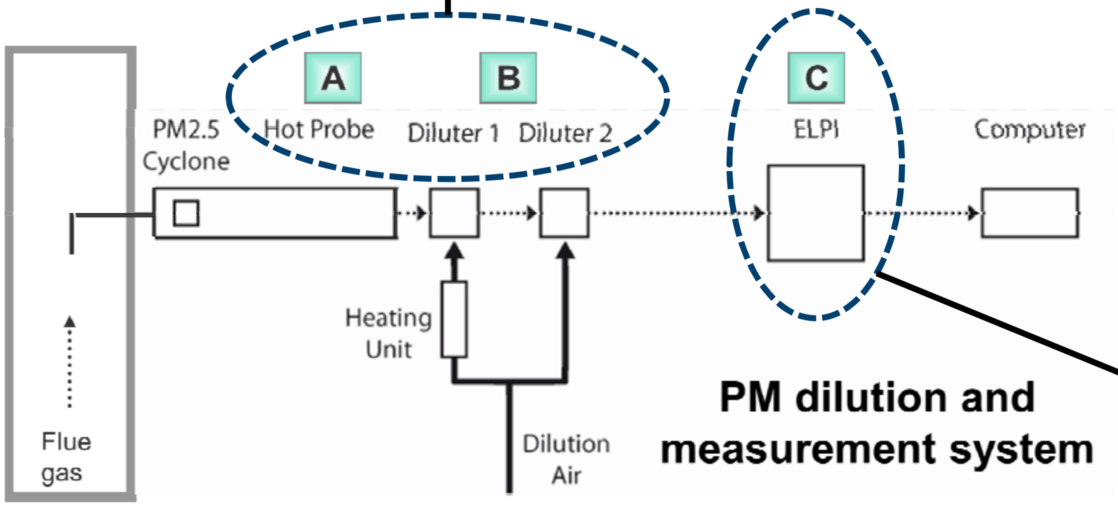
Measurement issues

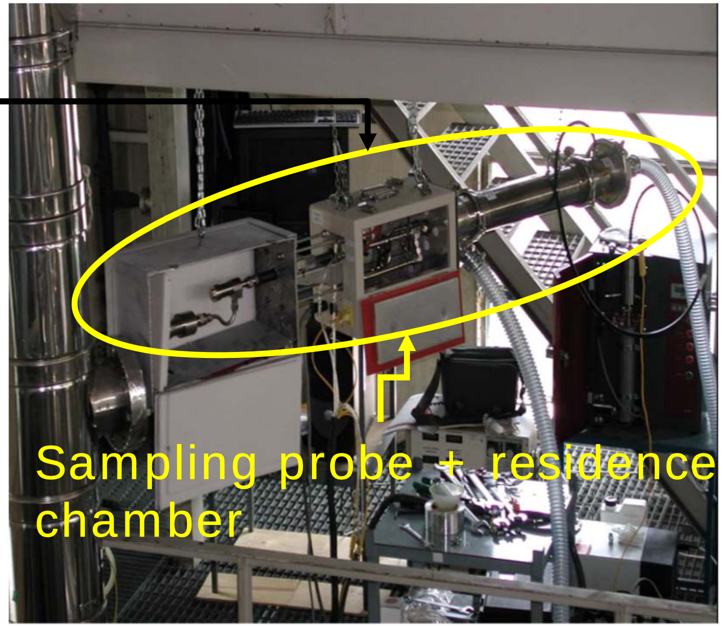
- no standard protocol
- significance in terms of number rather than mass
- contribution of condensable fraction from semivolatiles driven by atmospheric gas dilution





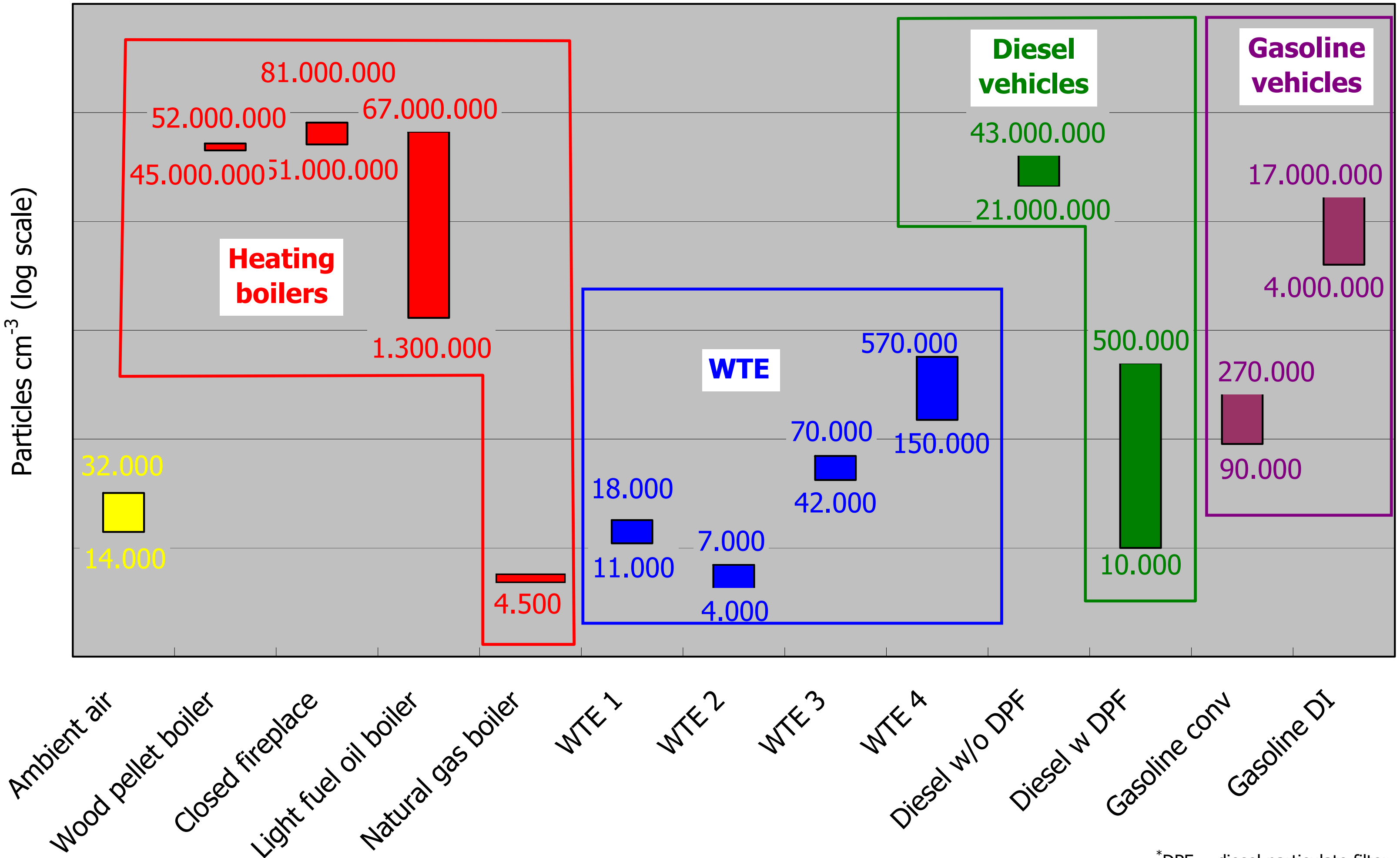
Sampling and measurement train





ELPI – LP Impactor
Range: 0.007 – 10 μm

Comparative evaluation of relevant technologies / applications



*DPF = diesel particulate filter

Assessment of Novel Technologies submitted to Regione Lombardia

Within the framework of a collaboration with Lombardy Region, MatER is in charge of analyzing and critically reviewing new projects of innovative waste treatment plants.

Projects examined so far

- Pyrolysis of Pulper Waste
- "Organic Molecular Sublimation" of industrial waste generated by the recovery of metal scraps
- Pyro-Distillation / Gasification of rubber residues
- Pyrolysis of used tires with energy recovery (direct and through the production of pyrolytic oils) and with material recovery (carbon black)
- Pyrolysis of solid material (sawdust, plastics, etc.) with vapor distillation for the production of liquid, gaseous and solid fuels for the steel industry
- Pyrolysis of resins and polymers for the recovery of the carbon fiber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WITHOUT MAKING A FEW ENEMIES
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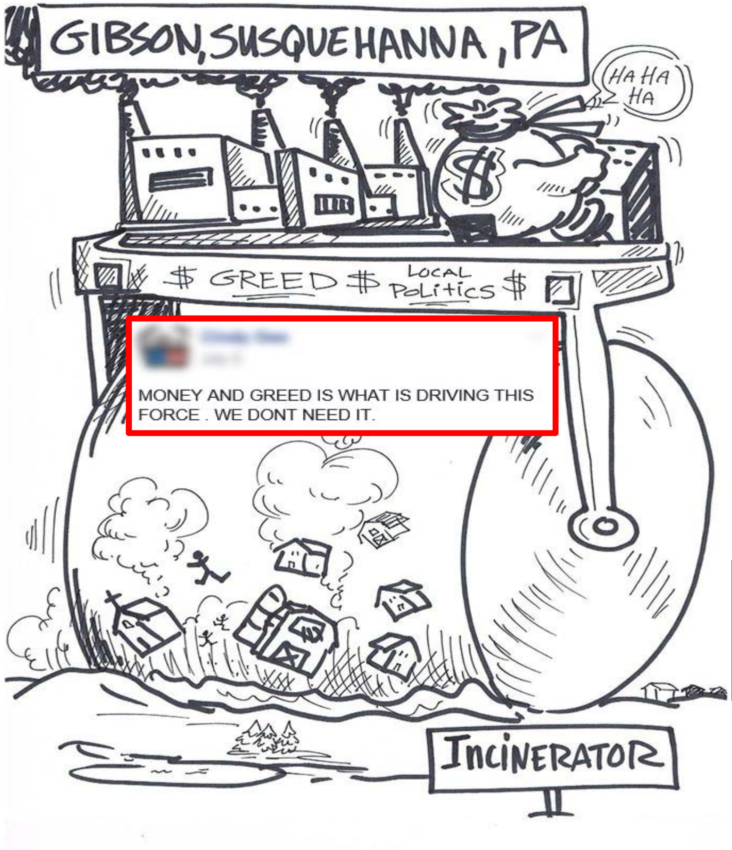
Not all "renewable" energy is created equal. Biomass and waste incineration is dirty energy.

Learn more: http://www.energyjustice.net/biomass



MONEY AND GREED IS WHAT IS DRIVING THIS FORCE . WE DONT NEED IT.

Global Alliance for Incinerator Alternatives (GAIA) Like Page

June 23 ·

Burning waste releases dioxin, which is dangerous for human health in even the smallest quantities.

High levels of dioxins found in chicken eggs sampled near waste incinerators and metallurgical...

(Beijing, China) High levels of dioxins and similar dangerous pollutants w

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20

Like Comment Share

Stop [redacted] Incinerator

September 29 at 2:47pm ·

According to EPA incinerators emit dioxin and other toxic chemicals. Incinerators also emit small particles called nanoparticles or ultrafines that measure less than 0.1 micron. Research shows Air pollution accelerates deposits in arteries that contribute to strokes and heart attacks.

America's super polluters

Industrial air pollution is strikingly concentrated among a small number of sites, a Center analysis found.

[redacted] The danger is the incinerator is located between a petrol station & landfill that leaks methane gas. It can create an explosion!

Like · Reply · September 26, 2014 at 1:59pm

Write a comment...

Collaboration with prof. G. Tipaldo, Univ. of Torino

3rd MatER Meeting

Innovation and Trends in Waste Management

May 22nd – 23rd, 2017

Politecnico di Milano, Piacenza Campus

Via Scalabrini 76, Piacenza

- **Session 1: Strategies and perceptions on waste management**

  Key-note speakers:

  - ✓ *Raffaello Cossu, Università degli Studi di Padova (Italy)*
  - ✓ *Paul Davison, Proteus Environmental Communications (UK)*

- **Session 2: Closing the loop: potentials and critical issues**

  Key-note speaker:

  - ✓ *Costas Velis, University of Leeds (UK)*

- **Session 3: Processes and technologies for energy recovery**

  Key-note speaker:

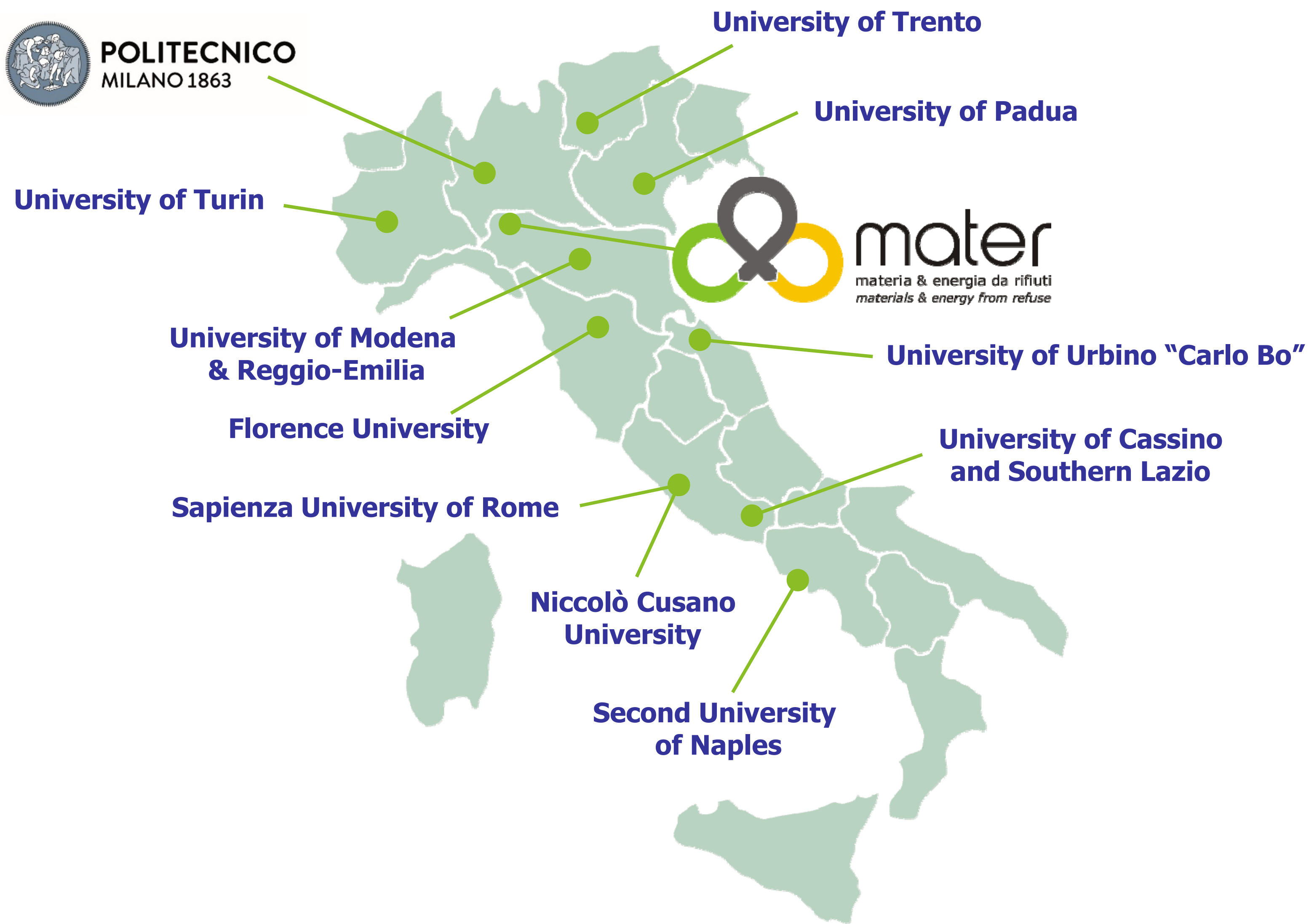
  - ✓ *Franz Neubacher, UVP Environmental Management and Engineering (Austria)*

- **Session 4: Processes and technologies for material recovery**

  Key-note speaker:

  - ✓ *Daniel Boeni, Managing Director WtE plant of KEZO, Hinwil (Switzerland)*

Waste Management in Italy: Research Groups & Universities



Prof. Giorgio Buonanno -University of Cassino and Southern Lazio

Lung cancer risk assessment at receptor site of waste-to-energy plants

- Estimate lung cancer risk related to ultrafine and coarse particles emitted from a WTE plant
- Use measured values of PAHs, heavy metals (As, Cd, Ni) and PCDD/Fs to estimate the Excess Lifetime Cancer Risk (ELCR):

$$ELCR = \frac{SF_i}{BW}\frac{m_i}{PM_{10}}\left(c_f \cdot \delta_s + \delta_M\right)$$

SFi: Inhalation Slope Factor describing the cancer potency of the i-th pollutant
BW: Body Weight of the receptor
$\mathbf{M_i}$: Mass concentration of the i-th pollutant present on the PM10 mass (mg/m3)
δ_S (nm^2/d): daily particle surface area
δ_M (mg/d): mass deposited doses

→ The estimated ELCR is used as input data in a numerical CFD model that solves the mass, momentum, turbulence and species transport equations

→ Study the influence of wind speed and chimney height on the ELCR at receptor sites ($ELCR_{RS}$)

- 4 different risk maps around the plant have been reconstructed:
  - → Combining meteorological data (wind speed and direction)
  - → Hypothesizing different exposure scenarios on the basis of time-activity patterns of people living nearby the incinerator.

Risk maps around the incinerator (15 km Radius) made on the basis of $ELCR_{RS}$ for different scenarios:

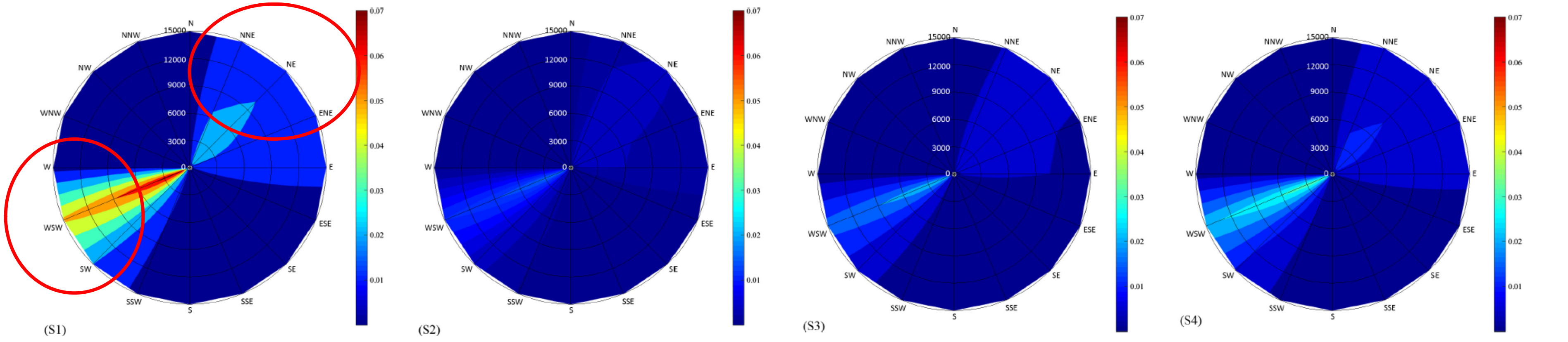
RS= Receptor Site
(at a breathable height of 1.5 m)

S1: People living nearby the incinerator 24 h/day outdoor **(Worst Case Scenario)**

S2 :people working nearby the incinerator 8 h/day indoor

S3: People working nearby the incinerator 8 h/day outdoor

S4: People living nearby the incinerator 16 h/day indoor



RESULTS:

- Both wind speed and chimney height noticeably influence the values of ELCR downwind at the plant, at the ground level.
- The most unfavorable conditions are relative to the locations at W-SSW and NNE-E for this plant.
- Maximum $ELCR_{RS}$ for S1= 0,07 x 10^{-5} at 3000m from the stack WSW (West-SouthWest) → Worst Case Scenario

→ For all the considered scenarios and for the specific plant analyzed, the maximum $ELCR_{RS}$ evaluated through the risk maps is lower to the WHO (World Health Organization) target risk (1 x 10^{-5})
(considering also that the adopted neutral and stable atmospheric boundary layer characteristic determine the worst condition for turbulent dispersion of pollutants in the atmosphere)

- With the increasing of wind speed, the ELCR value downwind at the plant decreases and its point of maximum risk becomes closer to the stack.
- Increasing the stack height decreases the ELCR, moving away from the stack the point of maximum risk.

Prof. Alessandra Polettini - Sapienza University of Rome

Solid waste treatment and valorization :

I. Solidification/Stabilization(S/S) of hazardous and non-hazardous industrial residues:

   1) Cement-based S/S of Air pollution Control Residues and bottom ash from WtE plants;

   2) Synthesis of geo-polymers from alumino-silicate containing residues;

II. CO_2 storage by accelerated carbonation of alkaline residues

III. Assessment of the Carbon footprint of waste management systems

IV. Assessment of the environmental behavior of raw and treated residues by leaching testing and leaching modeling

Anaerobic digestion of the organic fraction of urban and agro-industrial wastes:

I. Improvement of hydrolysis by ultrasonication in view of anaerobic digestion of lignocellulosic matrices;

II. Separation of AD phases for sequential biological production of H_2 and CH_4.

Remediation of contaminated soils and sediments:

I. Physico-chemical washing of metal-contaminated marine sediments

II. Electrokinetic treatment of metal-contaminated sediments and soils

Prof. Fabio Tatàno - University of Urbino “Carlo Bo”

I) Monitoring and evaluation of landfill gas emissions: multiyear experience at an Italian sanitary landfill

II) Combined biomethane potential and digestate characterization of selected agricultural and industrial residues/substrates

III) Urban and industrial waste streams of interest at provincial/regional levels

→ Focus on Province of Pesaro-Urbino:

- Biowaste Home Composting: Experimental Process Monitoring and Quality Control at the Provincial Territorial Scale
- Furniture wood wastes: property characterization and combustion tests

→ Focus on Marche Region:

- Industrial wastes from the leisure boat building sector
- Shoe manufacturing waste: characterization of properties and recovery options

Theme II) Biomethane – Uni/Research Cooperation

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“Chemistry of Materials & Wastes” Group, University of Modena & Reggio-Emilia

“Environmental-sanitary engineering” Unit, University of Urbino “Carlo Bo”

Agricultural & industrial organic residues with consistency & value at national/regional scale

- Biochemical Methane Potential tests in order to evaluate the “net” specific methane yields (NmL CH4 gVS-1)
- Detailed Chemical-Physical-Thermal characterisation of digestates

❖Better comprehension of bioenergy conversion process

❖Individuation of innovative reuse/recovery options for by-products

Prof. Marco Ragazzi – University of Trento

I) Design Criteria for Street Sweeping Waste Collection

❖ **Street Parameters**:

- Thanks to the collaboration with a waste collection company, an optimisation model for designing street sweeping waste collection systems is under development.
- The sweeping strategy (including manual activities) will be based on the characterisation of each street according to 12 parameters.
- The expected results are a lowering of costs and environmental impact.

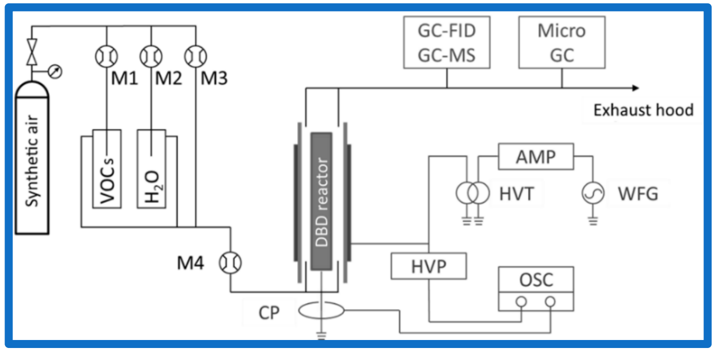
❖ **Tools Optimisation**:

- A detailed analysis of the efficiency of the machines suitable for street sweeping will be performed to allow a decrease of dust resuspension.

II) Management Of Criticalities From Odours

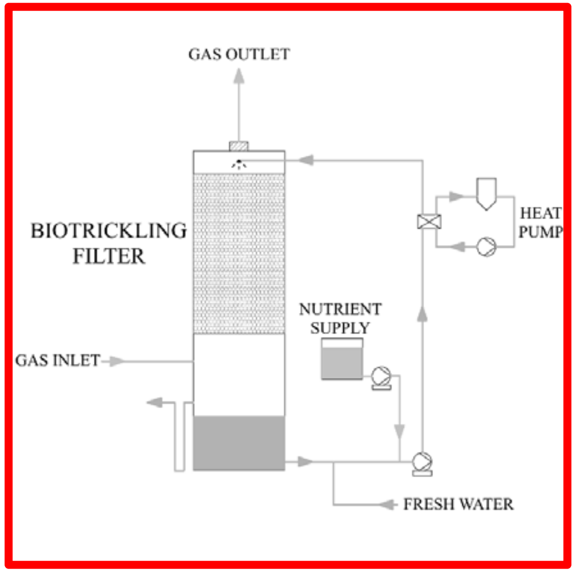
❖ Prevention:

A new model is under development for the management in real time of the biochemical aerobic processes in order to assure a correct biostabilization after the artifically aerated stage.
(on the contrary conventional solid respirometry needs a few days for the assessment of the respirometric index)



❖ Treatment:

Non thermal plasma (plasma at ambient temperature and pressure) can integrate the conventional approach based on open biofilter for the management of exhausted air generated from aerobic biochemical processes; a recent research developed in UNITN set a strategy for optimising energy consumption and configuration. Work is in progress for scaling up the results.



❖ Dilution:

Conventional open biofilters release the treated air under conditions unfavourable for dilution into the atmosphere. UNITN and UNINSUBRIA are working on the optimisation of biotrickling filters that guarantee a conveyed release of the treated air.

Prof. Ennio Carnevale - Prof. Lidia Lombardi

1) Energy recovery from waste and biomass through thermochemical processes

2) Landfills:

- Energy recovery
- Modelling of biodegradation dynamics in landfill
- Monitoring and measurement of fugitive landfill gas emissions

3) Energy recovery from biodegradable waste through biological processes:

- Biomethanation test in batch reactors (Biochemical Methane Potential, BMP test) and in continuous anaerobic digesters
- Innovative systems for the enhancement of biomethane
- Biohydrogen production from biodegradable waste

4) Material recovery from waste:

- Evaluation of the biological stability of organic matters as compost from source-selected organic fraction and compost from mechanical biological treatment plant
- Determination of the Dynamic Respirometric Index (DRI) through respirometric test and self-heating test

5) CO_2 removal and capture:

- Use of alkaline waste incineration residues (bottom ashes) for CO_2 capture from gaseous streams
- Innovative biogas up-grading processes

6) LCA of waste treatments and waste management systems

5) Innovative biogas up-grading processes

Use of alkaline solid residues from WTE for CO_2 capture

- **Process type:** CO_2 removal from biogas by KOH / NaOH solutions → production of bio-methane
- **Goal:** develop innovative processes
- **Methodology:** experimental tests, technical, economic and environmental evaluations
- **Tools:** Laboratory and pilot reactors

Prof. Umberto Arena - Second University of Naples

I) Fluidized Bed Gasification of biomass and waste

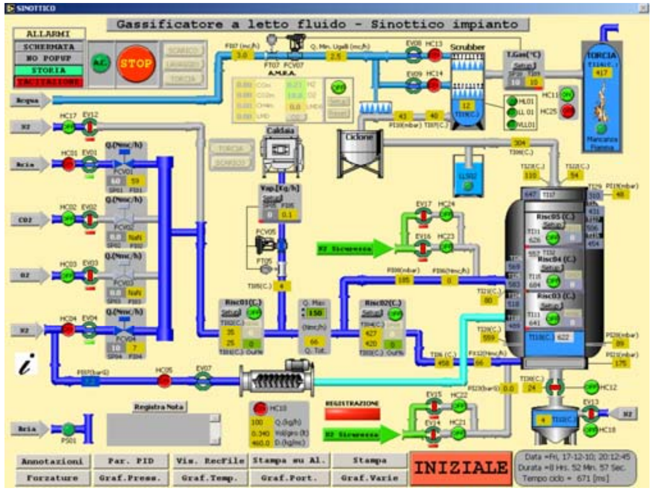
- Pilot-scale test for characterization of gasification behavior of biomass and different kind of wastes
- Technical support for process and executive design of FBGs
- Syngas cleaning methods for tar removal/cracking
- Assessment of FBG performances for innovative recycling systems

II) Assessment Tools for Waste Management and Resource Utilization

- Life Cycle Assessment and Material/Substance Flow Analysis of technologies for recycling, biological and thermal treatment of MSW
- LCA of Waste Management Plannings
- LCA of innovative solutions for industrial waste management

I) The FluGas pilot-scale FBG

Geometrical parameters	**ID: 0.381m; total height: 5.90m; reactive zone height: 4.64m; wall thickness:12.7mm**
Feedstock capacity	100 kg/h
Thermal output	up to about 400kW
Typical bed amount	145 kg
Feeding system	over-bed air-cooled screw feeder
Gasifying agents	Air (but also: oxygen, steam, carbon dioxide)
Range of bed temperatures	700-950°C
Range of fluidizing velocities	0.3-1m/s
Flue gas treatments	cyclone, scrubber, flare
Safety equipment	water seal, safety valves, rupture disks, alarms, nitrogen line for safety inerting



Conclusions

Recovery from Waste rarely appears in the agenda of major national and international research programs

Yet efficient and environmentally benign Waste Management is key to the accomplishment of a Sustainable Economy

There is a strong need for unbiased research and rigorous education in a number of areas spanning from Thermodynamics to Economics, from Material Science to Sociology

MatER aims at giving a significant contribution to fill this gap, wherever possible in coordination with research groups in Italy

International cooperation with sister organizations of the Global WTERT Council can greatly enhance the effectiveness of this effort

A special thank to all the colleagues who have contributed to this presentation

proff. S. Cernuschi, M. Grosso, M. Giugliano, L. Rigamonti, F. Viganò – MatER / Politecnico di Milano

prof. G. Tipaldo – University of Turin

prof. U. Arena – Second University of Naples

prof. G. Buonanno – University of Cassino

proff. E. Carnevale, L. Lombardi – University of Florence / Univ. N. Cusano

prof.ssa A. Polettini – University of Rome "La Sapienza"

prof. M. Ragazzi – University of Trento

prof. F. Tatàno – University of Urbino "Carlo Bo"

and many thanks to all of you

for your attention !

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