mater
materia & energia da rifiuti
materials & energy from refuse

IRRC WASTE-TO-ENERGY

Vienna Marriott Hotel, Vienna, Austria
18-19 September 2017

Impact of the increased fraction of industrial waste on the emissions from waste-to-energy plants

Federico Viganò
Department of Energy - Politecnico di Milano
LEAP Lab & MatER Study Center

The MatER (Materials and Energy from Refuse) Study Center

Research Center established at the end of 2010

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.

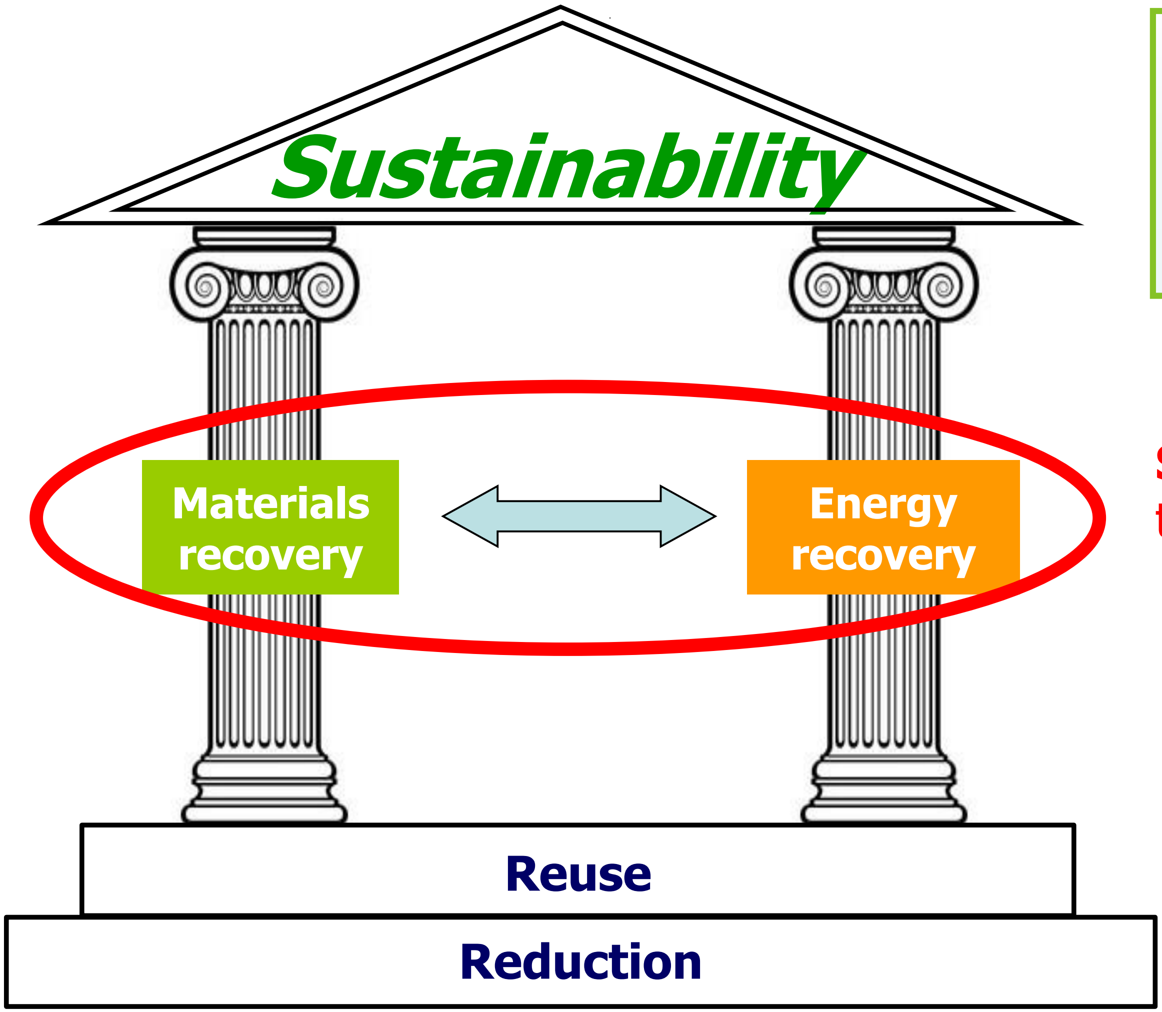
mater
materia & energia da rifiuti
materials & energy from refuse

Support of public and industrial partners

POLITECNICO MILANO 1863 | LEAP Laboratorio Energia e Ambiente Piacenza | UTILITALIA imprese acqua ambiente energia
iren ambiente | a2a | HERAmbiente
LGH LINEA GROUP HOLDING | Brianza Energia Ambiente | HestAmbiente Società del Gruppo Herambiente

MatER has established strong relationships with International research centers & Networks:

WTERT | ISWA International Solid Waste Association | ATIA ISWA ITALIA | PREWIN NETWORK

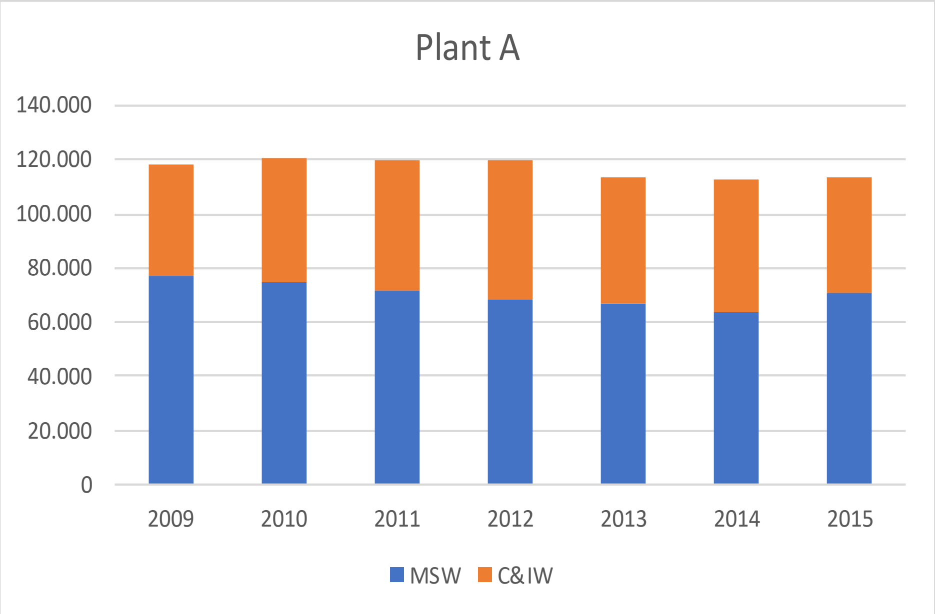


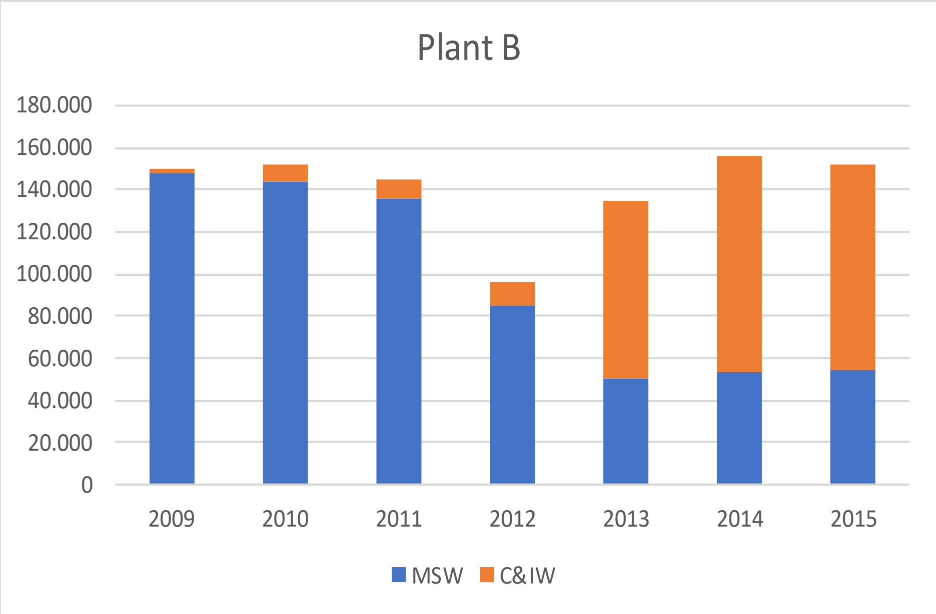
Materials and Energy recovery are <u>BOTH ESSENTIAL</u> for Sustainability

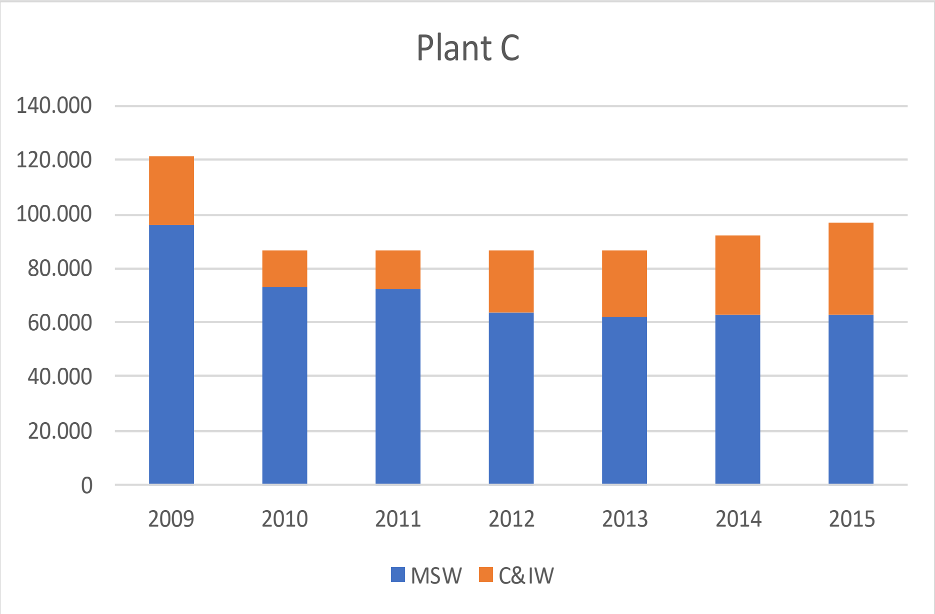
Strict interconnection between the two forms of recovery:

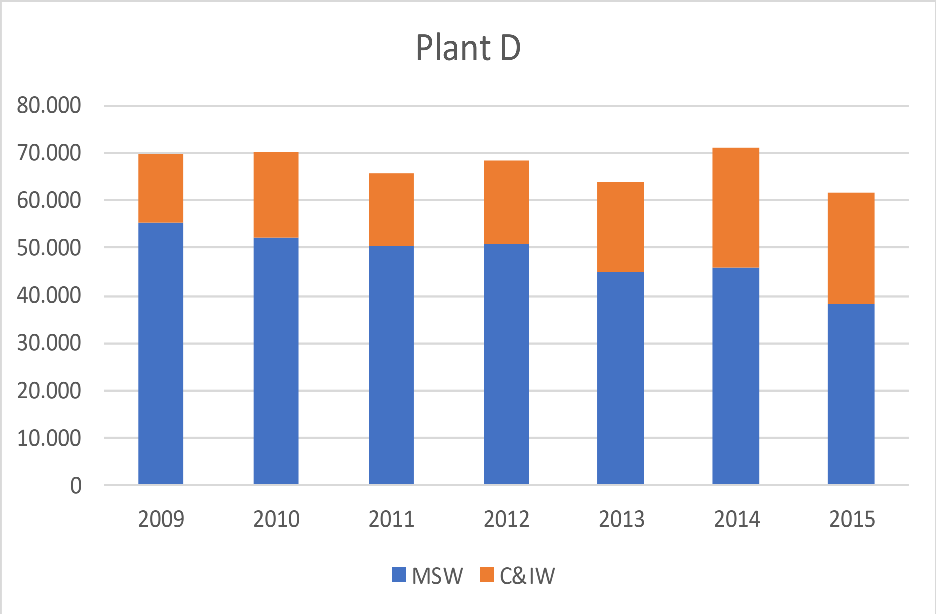
- Materials recovery generates residues that can be sent to energy recovery
- Energy recovery generates residues that can be sent to materials recovery

Increased fraction of industrial waste to WtE plants









MAIN CONCERN with the increased fraction of C&IW

DO EMISSIONS INCREASE?

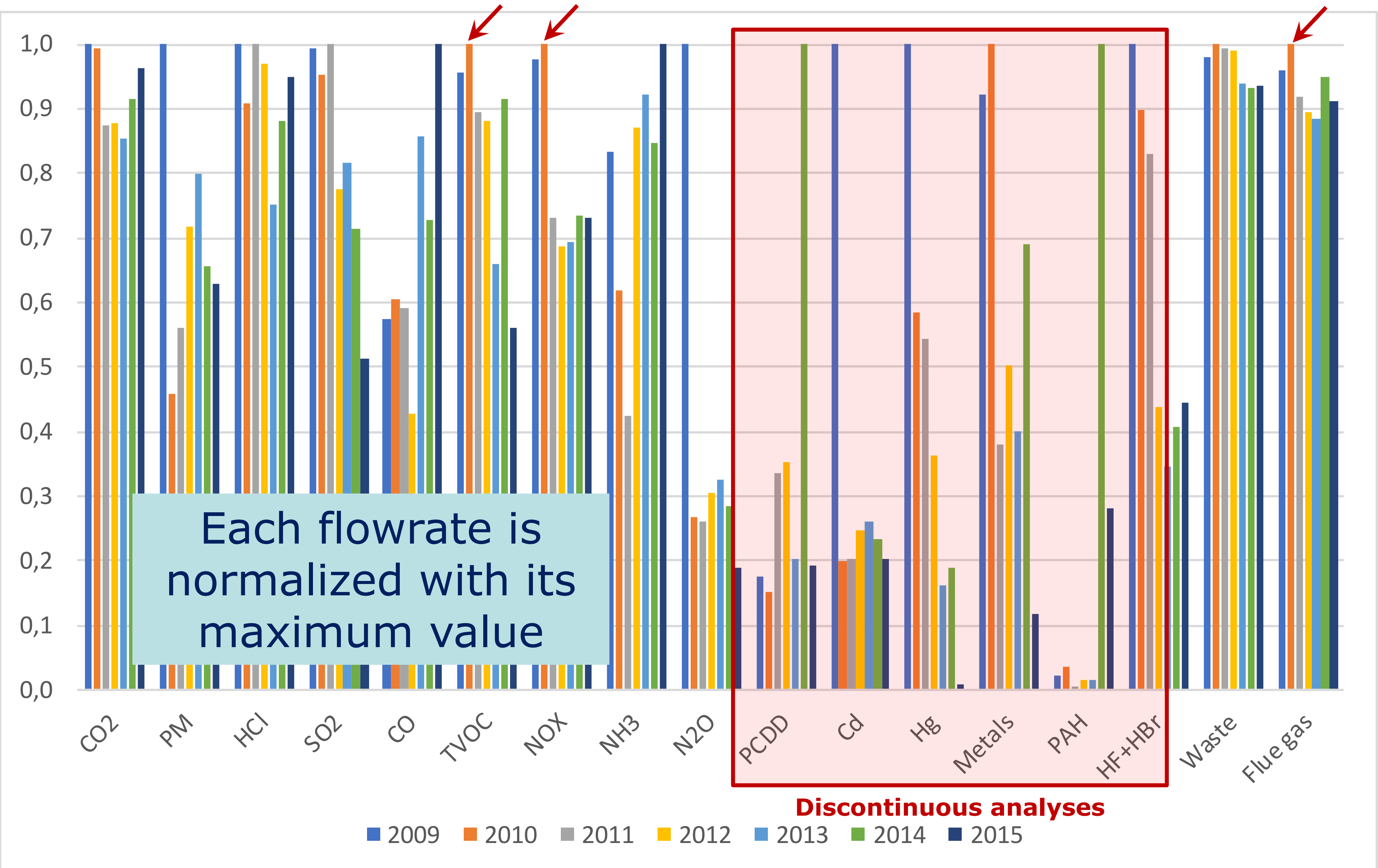
In addition to peculiar pollutants, possibly brought by specific waste streams
IS THERE ANY EFFECT ON THE EMISSIONS OF GENERAL POLLUTANTS?

EMISSION [kg/s] = FLOWRATE OF FLUE GAS [Nm^3/s] x CONCENTRATION [kg/Nm^3]

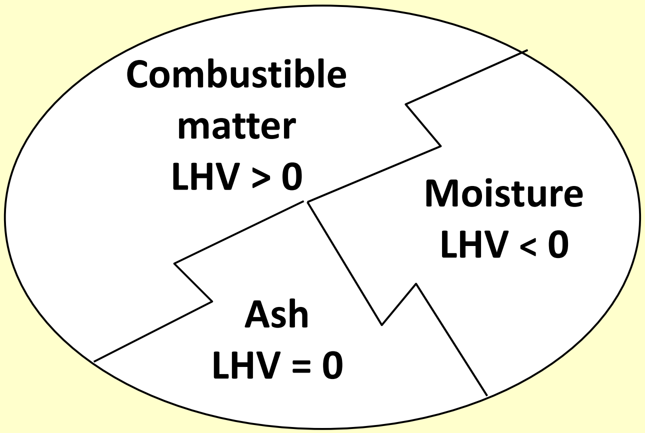
The CONCENTRATION on Dry, Normalized, Referred to 11% O_2 (DNR) basis of a pollutant, which is controlled by APC system (eg. NO_X, HCl), can be assumed CONSTANT as far as the plant is operated within its design limits

HOW does the flowrate of flue gas (DNR) depend on the nature of the treated waste?

The case of plant A:



The nature of the treated waste



For the purpose of mass and energy balance of combustion, this simple scheme is adequate.

Ash: inert materials that do not participate actively to combustion

Moisture: liquid water that absorbs its latent heat of evaporation (= LHV = -2.44 MJ/kg) during combustion

Combustible matter: peculiar of each different substance contained in the waste

Properties of waste combustible matter

Survey of data on combustible matter (DAF = Dry Ash Free basis) of materials that can be reasonably sent to WtE plants

10 literature sources (collections of data)

460 records

of which **~400** on possible waste materials

classified according to **14** categories (eg. paper, plastics)

Properties considered:

H/C, O/C, N/C, … ratios

C, H, O, N, … mass contents

LHV

DAD: Day Air Demand for stoichiometric combustion (Nm^3/kg_{DAF} and Nm^3/MJ_{DAF})

DSFG: Dry Stoichiometric Flue Gas production (Nm^3/kg_{DAF} and Nm^3/MJ_{DAF})

Results of the survey:

Mass balance can be well simulated by considering only C, H and O contents, with the balance being N

→ Mean error on the prediction of DAD and DSFG (Nm^3/kg_{DAF}) ≈ 0

→ Corresponding std. deviation ±1.2% (due to the error in the evaluation of the molar mass)

→ $dad_{DAF} = f(y_C, y_H, y_O)$; $dsfg_{DAF} = g(y_C, y_H, y_O)$

LHV_{DAF} calculated by linear correlation of C, H, O, N contents

→ Boie's correlation is the best among 10 linear correlations

→ $LHV_{DAF} = 0.3517*y_C\% + 0.944*y_H\% - 0.111*y_O\%$ $(+0.1047*y_S\%)$

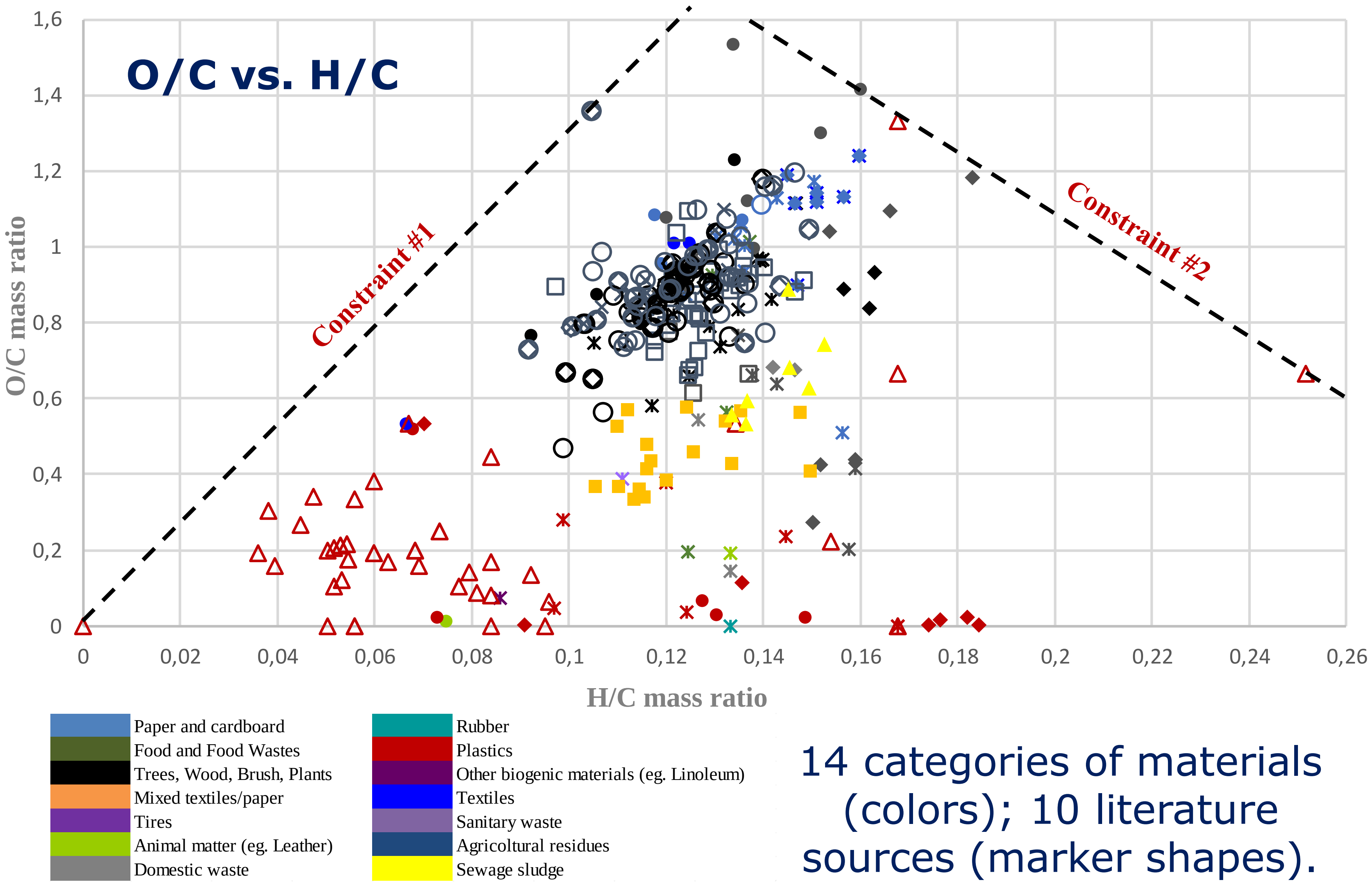
→ Mean error on the prediction of LHV ≈ 0

→ Corresponding std. deviation (σ) ±9.0%

→ $LHV_{DAF} = h(y_C, y_H, y_O)*(1+x)$ with x in $[-2\sigma, +2\sigma]$ for 95% of cases

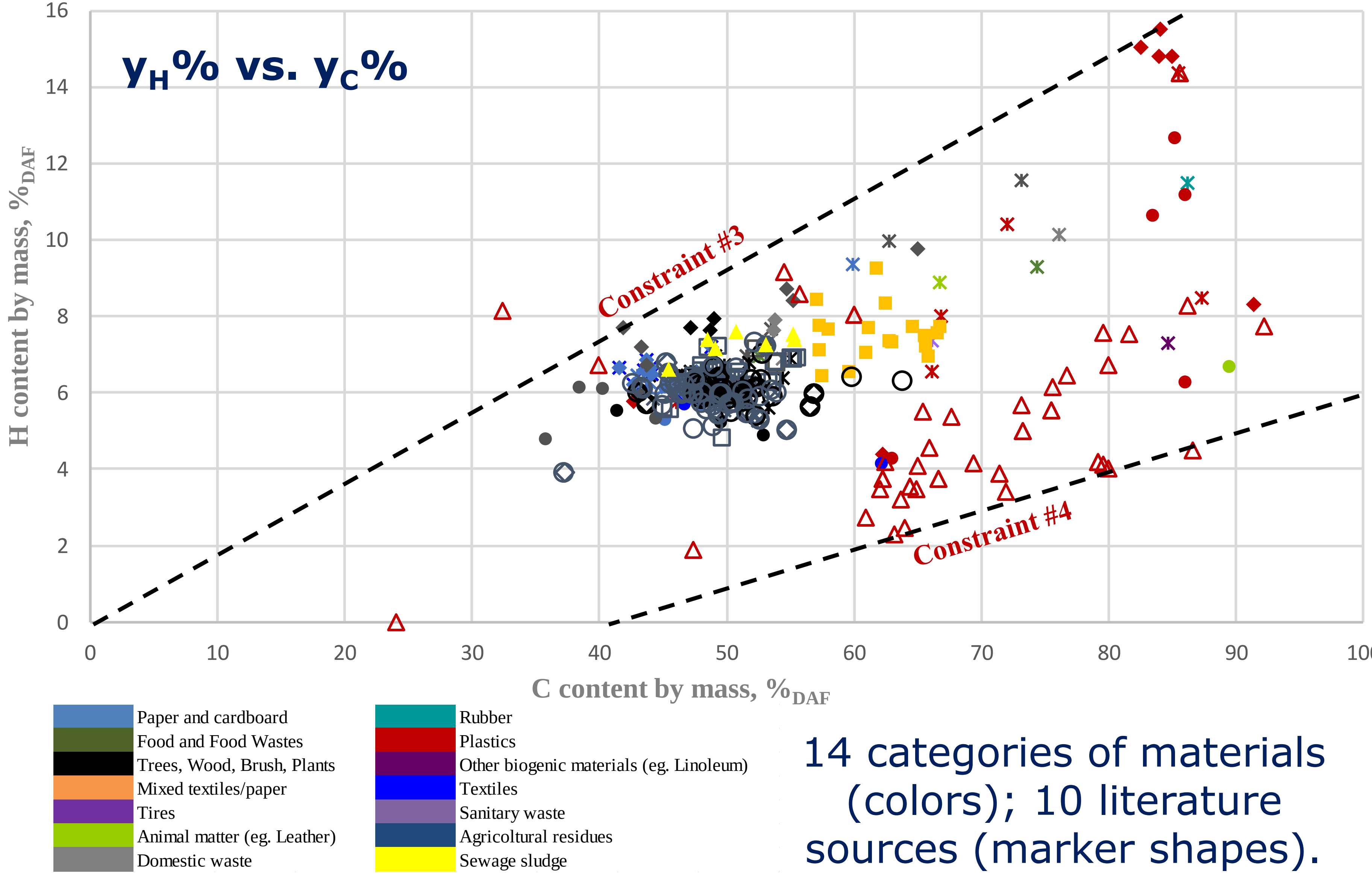
Some ranges of variation are identified for properties

Properties of combustible matter



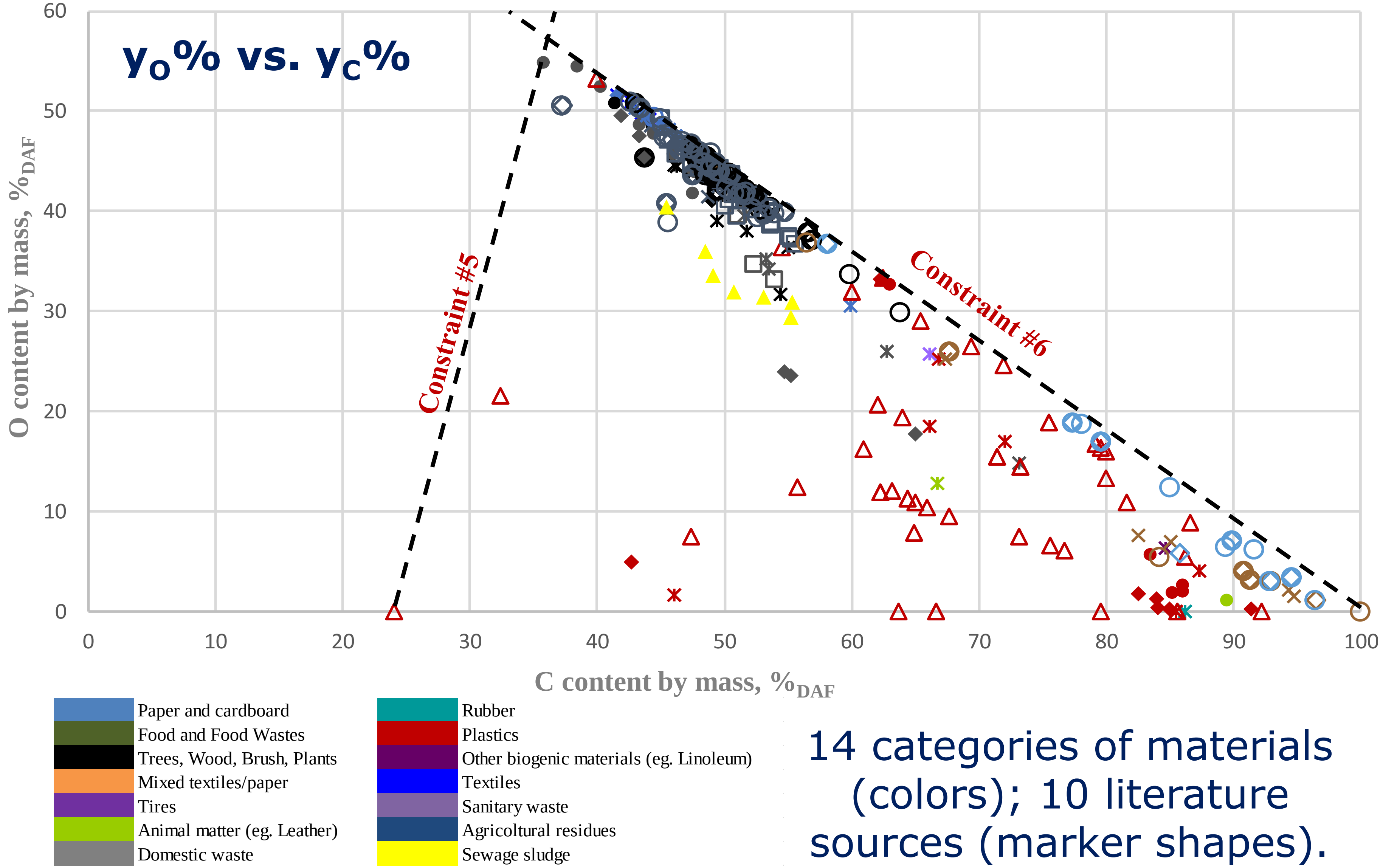
14 categories of materials (colors); 10 literature sources (marker shapes).

Properties of combustible matter



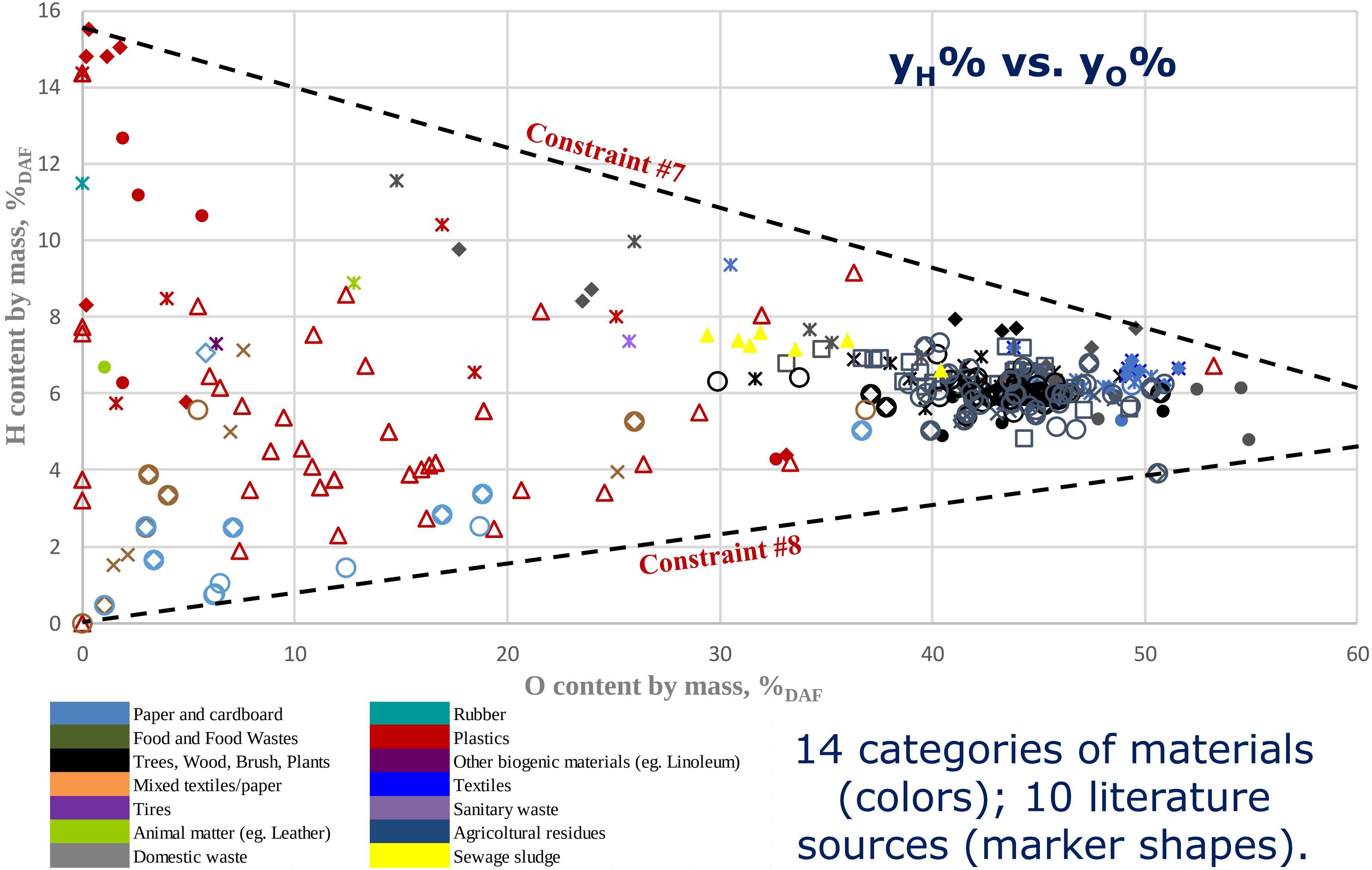
14 categories of materials (colors); 10 literature sources (marker shapes).

Properties of combustible matter



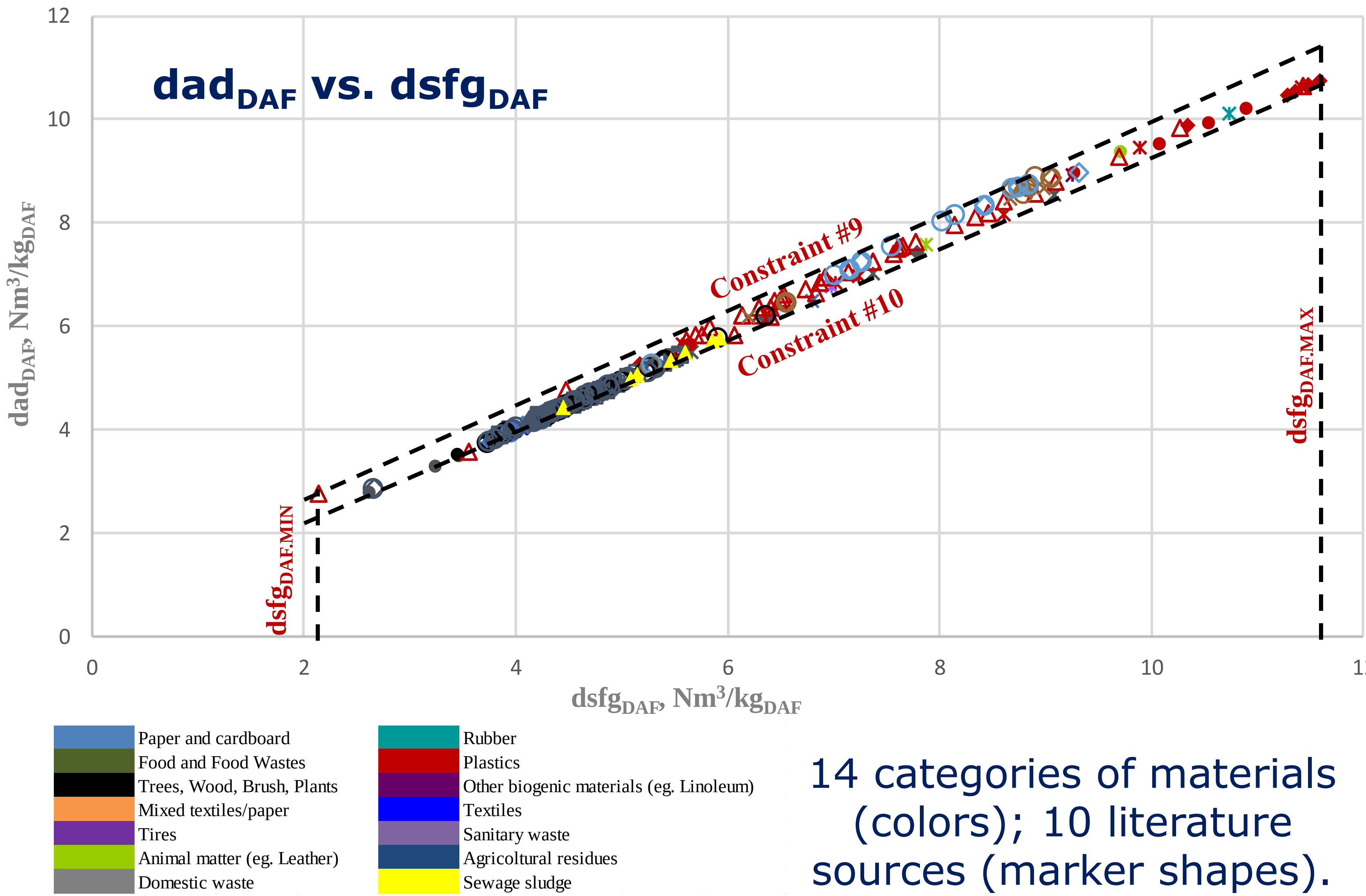
14 categories of materials (colors); 10 literature sources (marker shapes).

Properties of combustible matter



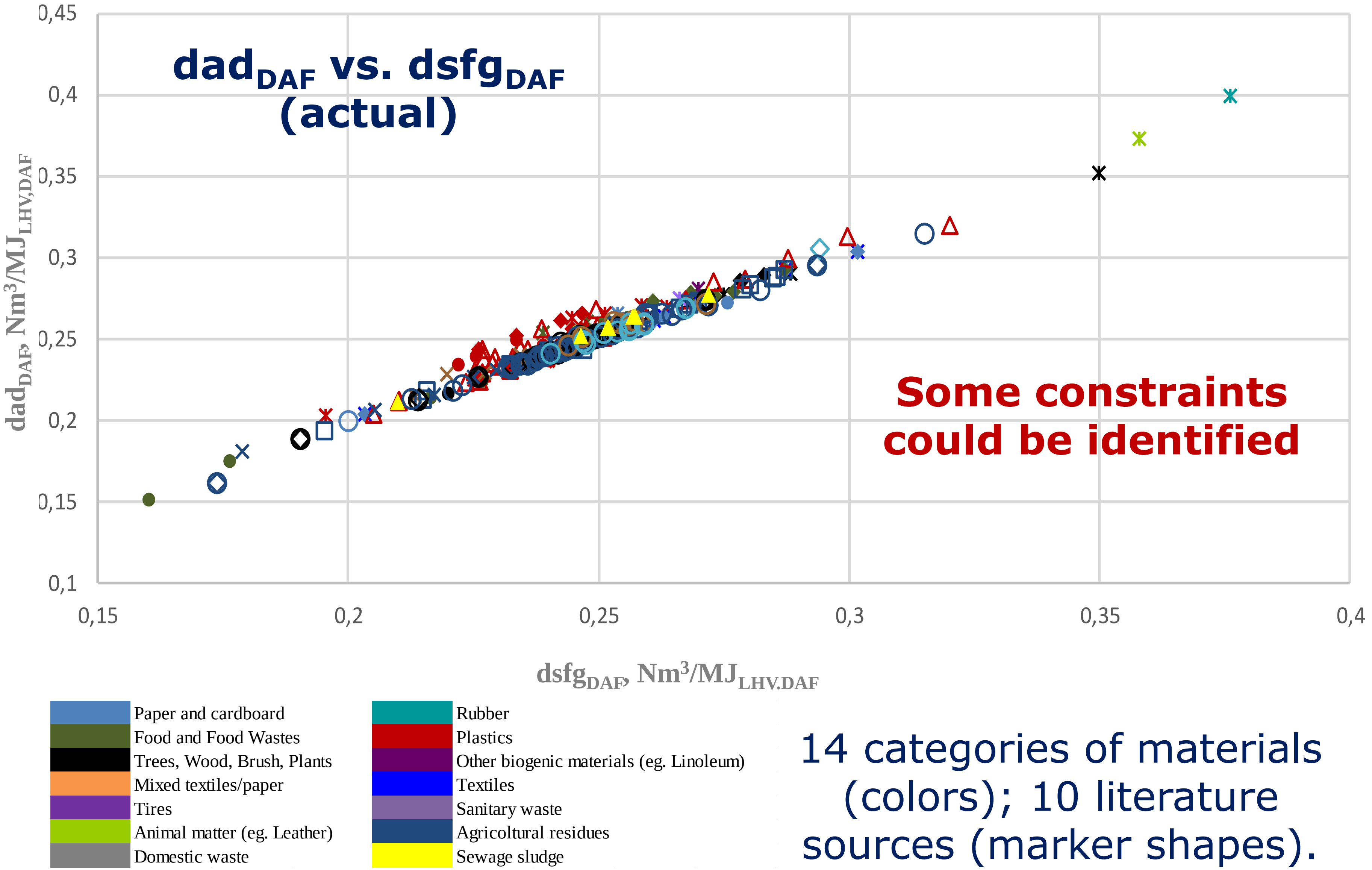
14 categories of materials (colors); 10 literature sources (marker shapes).

Properties of combustible matter



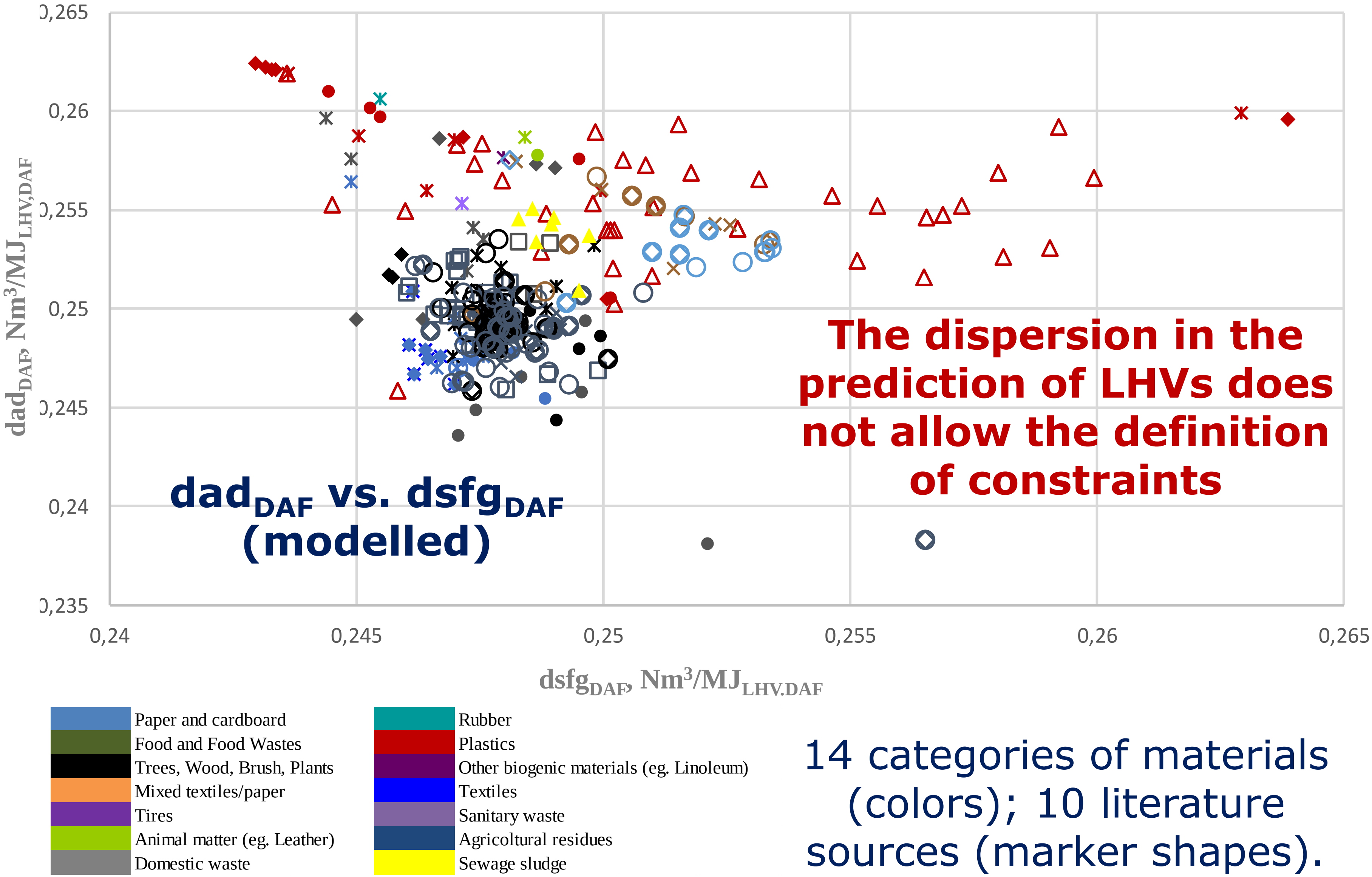
14 categories of materials (colors); 10 literature sources (marker shapes).

Properties of combustible matter



14 categories of materials (colors); 10 literature sources (marker shapes).

Properties of combustible matter



dad$_{DAF}$ vs. dsfg$_{DAF}$ (modelled)

The dispersion in the prediction of LHVs does not allow the definition of constraints

14 categories of materials (colors); 10 literature sources (marker shapes).

THEREFORE

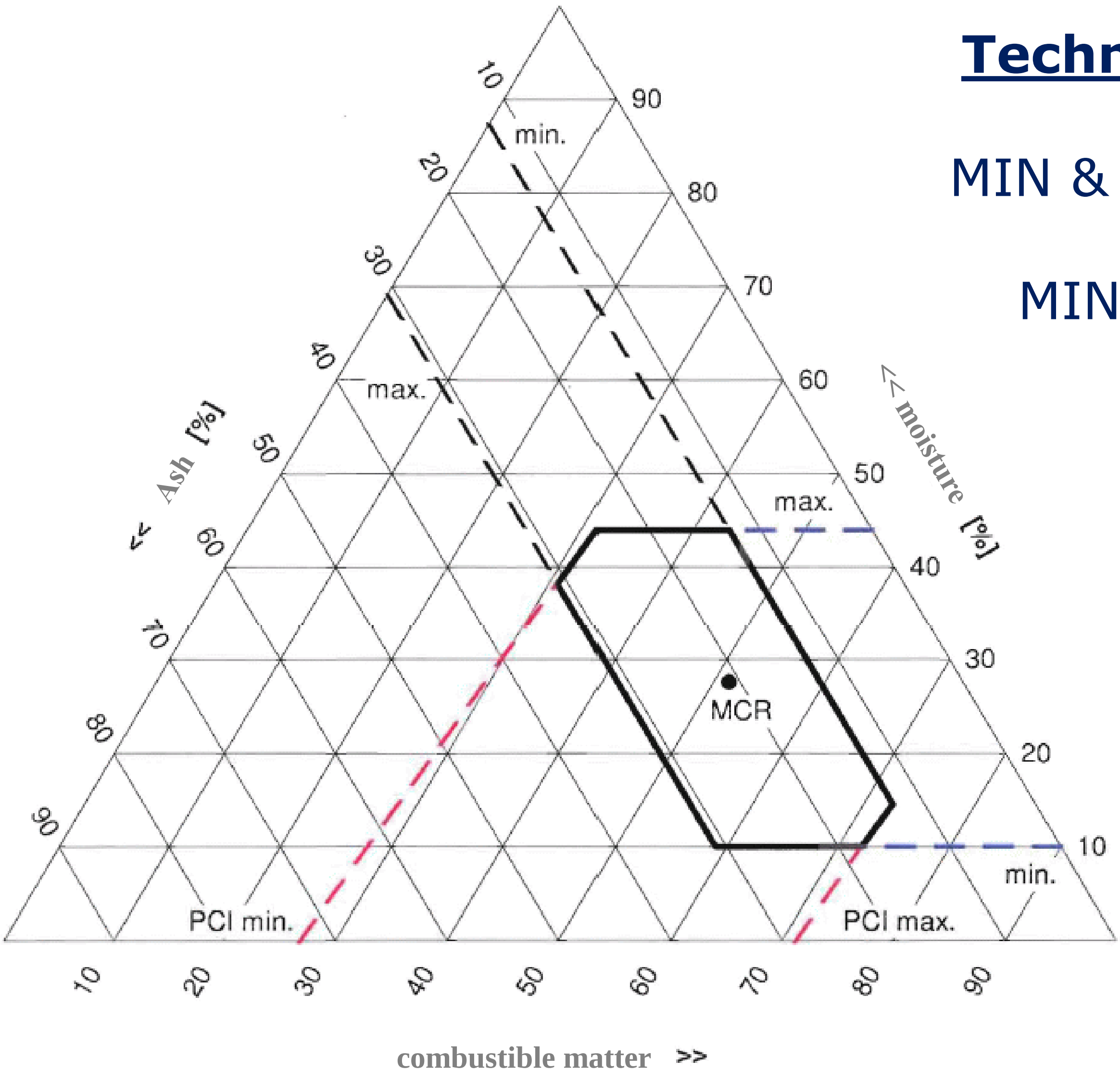
Any waste can be modelled as a mix of six components:

C, H, O, N, Ash, Moisture

- **The properties characterizing such a mix are subjected to some constraints (12 have been found)**
- **LHV can be predicted based on such properties with ±18% accuracy at ~95% confidence level**

When the waste is fed to a WtE plant, its properties must also respect technological and operating limitations (i.e. other constraints)

Tanner's diagram for the combustor



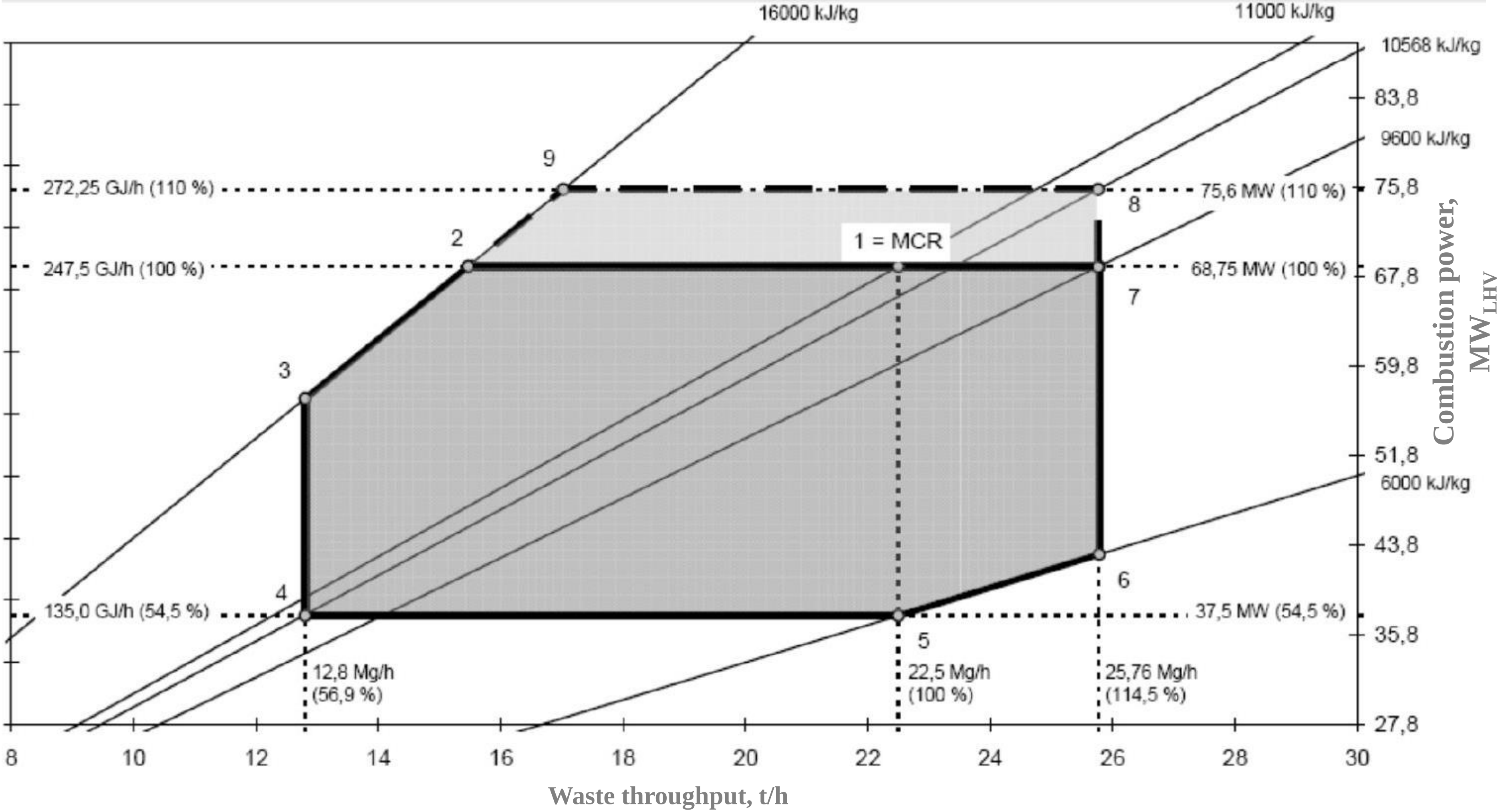
Technological limitations

MIN & MAX moisture content

MIN & MAX ash content

MIN & MAX LHV

Combustion diagram



Technological and operating limitations

Let's focus on MCR combustion power → $LHV*M_W = P_{COMB,MCR}$

MIN & MAX for waste throughput → $M_{W,MIN} < M_W < M_{W,MAX}$

Again MIN & MAX LHV

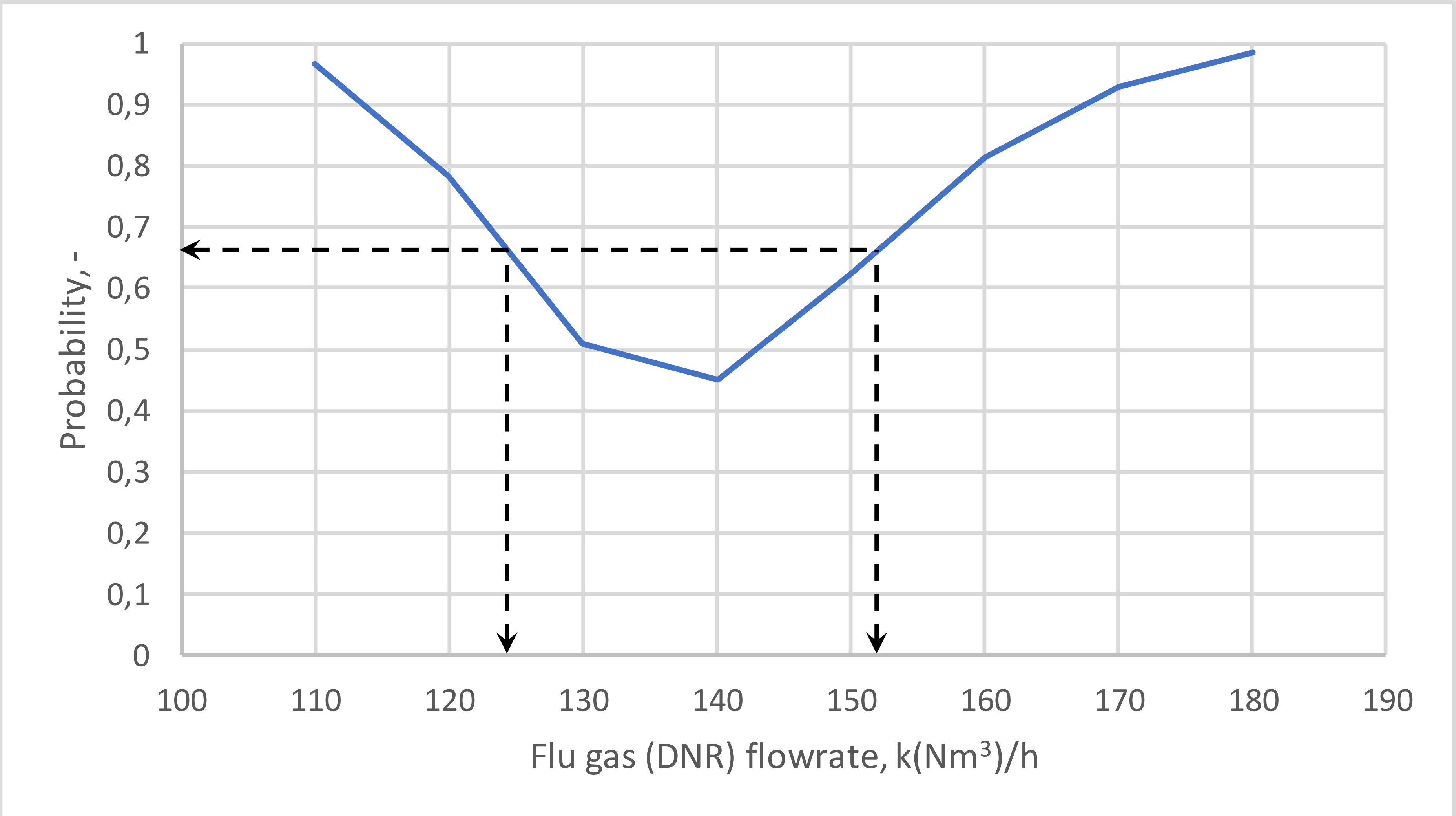
Mathematical problem

Find MAX and MIN of FG_{DNR}:

- **6 variables: M_N, M_H, M_O, M_N, M_{Ash}, M_{Moist} (kg/s);**
- with assigned P_{COMB} (linear function of the 6 variables) → **linear equality constraint**;
- under the **6** natural (**linear**) **inequality constraint** (every variable > 0);
- under **12** (**linear**) **inequality constraints** for DAF properties;
- under **6** (**linear**) **inequality constraints** due to technological limitations (y_{Ash}, y_{Moist}, LHV);
- under **2** (**linear**) **inequality constraints** due to operating limitations (M_W);
- under **1** additional (**linear**) **equality constraint** to limit weird solution ($y_{N,DAF}$ = 1% by mass).

For each level of confidence in the estimate of LHV_{DAF} → a linear programming problem in 6 variables with 26 inequality constraints and 2 equality constraints

Results



FG_{DNR} falls in [124 – 152] $k(Nm^3)/h$ @ ~65% conf. → 138 $k(Nm^3)/h$ ±10%

FG_{DNR} = 145 $k(Nm^3)/h$ ±24.5% @ ~95% confidence level

Conclusions

- The influence of the nature of the treated waste was investigated with respect to the production of FG_{DNR}
- Some constraints on the possible values of waste properties were identified based on a survey of literature data
- The behavior of a WtE plant was simulated based on the constraints that represent technological and operating limitations
- Although the very conservative approach, the analysis showed that:
    - FG_{DNR} basis are known ±10% @ ~65% c.l.
    - or ±25% @ ~95% c.l.
- This is valid for any type of waste: MSW as well as C&IW – In fact no evidence of distinctive patterns was found
- These results apply to the emissions of those pollutants that depend mainly on FG flowrate

THANKS FOR YOUR ATTENTION!!

POLITECNICO
MILANO 1863

mater
materia & energia da rifiuti
materials & energy from refuse

mater@polimi.it
www.mater.polimi.it