"Critical" Issues for PM_{10} Emission Inventory Realization at Local, Regional and National Level in Italy

Carlo Trozzi, Rita Vaccaro, Stefano Crocetti, Monica Pantaloni, Christian Melis, Antonella Bernetti, Daniele Didero

Techne Consulting srl -Via G. Ricci Curbastro 34, Roma (Italy)

carlo.trozzi@ techne-consulting.com

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carlo.trozzi@ techne-consulting.com

introduction

- the state of the art in the realization of several PM_{10} regional and local emission inventories in Italy is discussed with particular attention to the main "critical" issues that such activity involves
- the authors were been involved in realization of emission inventories at regional level (Liguria, Umbria, Friuli Venezia Giulia, Toscana, Campania), provincial level (Firenze, Cagliari, L'Aquila, Roma, Trento, Bolzano) and urban level (Firenze, Livorno, Lucca)

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carlo.trozzi@ techne-consulting.com

topics

- summary of methodology and software for emission inventory preparation at local level
- discussion on a lot of critical issues for PM_{10} emission inventory realization:
  - SNAP Nomenclature of activities
  - main sources
  - modeling of emissions in some critical sectors
- short discussion of the application of US EPA DARS scheme to assign uncertainty to local emission inventories

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Emissions inventory

- nomenclature used follows the CORINAIR UNECE TASK FORCE guidelines
- Pollutants:
  - five main air pollutants: NO_x, SO_x, VOC, CO, PM_{10}
  - heavy metals: As, Cd, Cu, Cr, Hg, Pb, Zn
  - greenhouses gases: CO_2, CH_4, N_2O
  - ammonia (NH_3)
  - benzene (C_6H_6)
  - polycyclic aromatic hydrocarbons (PAHs)

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Emissions inventory time and space

- **sources are generally split in:**
  - **point sources: fixed sources for which the total annual emissions of one pollutant are larger than a fixed threshold value, evaluated at source location**
  - **linear/nodal sources: main communication ways (road, river, railway, and seaway) and nodes (airports, ports) evaluated one by one and disaggregate to 1km x 1km mesh level**
  - **area sources (all the others) evaluated at the municipal level and disaggregate to 1km x 1km mesh level**
- **annual emissions are at first evaluated**
- **hourly emissions are estimated through the use of corrective factors (for example: typical working hours, temperature, monthly selling of fuels, etc.)**

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Thresholds for Main/Minor point Sources

Pollutant	Minor point sources	Main point sources
Carbon Monoxide	50 t/year	250 t/year
Other main pollutants	5 t/year	25 t/year
Heavy metals	50 kg/year	250 kg/year

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APEX (Air Pollutants Computer System)

- manage inventories from NUT1 to LAU2
- originally developed, ten years ago, as a computer system in Visual Basic language
- natural evolution of national system developed for ENEA eighteen years ago in the frame of first CORINAIR experiment
- available with an ORACLE, SQL Server or ACCESS
- uses ArcView or Mapinfo for thematic map
- allow the emissions estimate in different media such as water, wastes, noise

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APEX functions

- manage input data for emissions estimate and sources description
- contains an emission factors data base
- contains tools and data for spatial and temporal allocation and chemical speciation
- produce reports and graphics about input data and emissions estimates
- produce high quality maps about input data and emissions estimates with the interface to geographic information systems

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APEX balances and perspectives

- more then fifteen local public administrations (regions, provinces, municipalities, local Environmental Protection Agency offices) use today the software
- recently the new APEX 4.1 release introduce tools for evaluating uncertainty in emission inventories
- work are in progress to develop a new version of the system, APEX.com, in web environment as a part of a more general project to develop a complete tool to manage air quality (AirSuite.com)

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SNAP and PM10 inventory

- the needs of a new definition of SNAP nomenclature of activities was discussed by the authors since the 1st Joint UNECE Task Force on Emission Inventories and Projections held in Rome in 2000
- in the following these topics are discussed with particular attention to the introduction of new activities and of a structured fourth level of detail behind the group, section, activity structure and besides fuel classification [if applicable]; the new level must be introduced to define processes and control technologies

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national and local SNAP

- SNAP classification is the reference classification non only for national but also for sub-national inventories
- two main problems:
  - the classification must be simple for national reporting use
  - the classification must be detailed for definition of emission factors and for reference in local emission inventories

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SNAP rubric and LAU2 level

- using the actual SNAP classification the problem is resolved with the free use of "rubrics"; this practice can produce as results difficult comparison from different inventories and ambiguous comparison of emission factors for the same activities
- the development of sub - regional emission inventories produces an increasing use of SNAP at municipal (LAU 2) level; in this inventories the emission estimates were obtained at a more accurate level including the subdivision of activities in different technologies; the subdivision of activities facilitates also the use of guidebook emission factors

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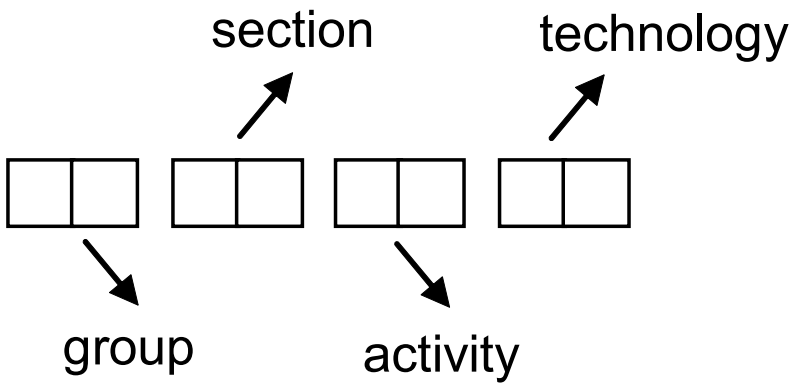
Actual sub-national E-SNAP

- actually, the solution adopted in our local experiences is to maintain the structure of actual SNAP, introducing where useful new activities behind the last one in each sector, and introducing a new two-digit code for technology. In the following we refer to this classification as E-SNAP (extended SNAP)



- This solution is not completely satisfactory for PM10.

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Actual E-SNAP example

Group Section Activity Technology
01 COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRIES
01 01 Public power
01 01 01 Combustion plants >= 300 MW (boilers)
01 01 01 00 Generic (unknown)
01 01 01 10 Dry Bottom Tangential fired
01 01 01 20 Dry Bottom Wall/Vertical fired
01 01 01 30 Wet bottom Wall fired
01 01 01 40 Circulating Fluidised bed
01 01 01 50 Pressurized fluidised bed
01 01 01 60 Grate firing
…
09 WASTE TREATMENT AND DISPOSAL
…
09 02 Waste incineration
09 02 01 Incineration of domestic or municipal wastes
09 02 01 00 Generic (unknown)
09 02 01 10 Mass Burn Waterwall Combustor
09 02 01 20 Mass Burn Rotary Waterwall Combustor
09 02 01 30 Mass Burn Refractorywall Combustor
09 02 01 40 Modular Excess Air Combustor
09 02 01 50 Modular Starved Air Combustor

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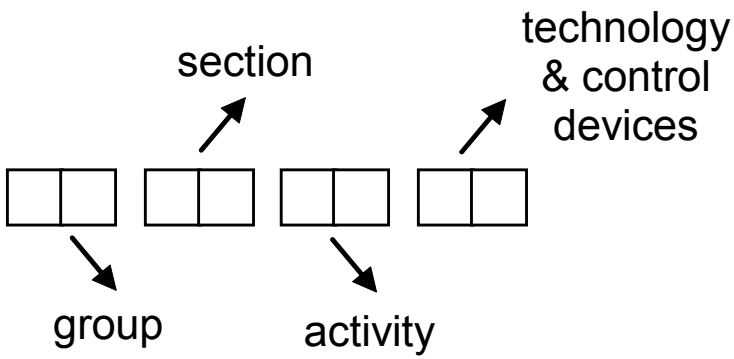
Future sub-national E-SNAP

- **Work are in progress to introduce in the E-SNAP the definition of emission control devices**
- **To define control devices we can use a classification that takes into account:**
  - **pollutant classes: acidificant (SOx, NOx, NH3), organic (VOC as class and individual ones) and particles (in the following the classes are referred as: "A", "O" and "P");**
  - **control efficiency classes: high (greater than 90%); moderate (between 40% and 90%) absent (less than 40%), in the following the classes are referred as "HE", "ME", "N".**
- **Despite the control technologies are specific for every pollutant it is useful to define combined categories of control technologies as specific codes of the E-SNAP. In such classification can be defined standard configurations of control technologies (for example DESONOX and ESP for power plants as HEA + HEP).**



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Future E-SNAP example

Group Section Activity Technology	
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRIES
01 01	Public power
01 01 01	Combustion plants >= 300 MW (boilers)
…	
01 01 01 10	Dry Bottom Tangential fired – NA and NP
01 01 01 11	Dry Bottom Tangential fired – NA and MEP
01 01 01 12	Dry Bottom Tangential fired – NA and HEP
01 01 01 13	Dry Bottom Tangential fired – MEA and NP
01 01 01 14	Dry Bottom Tangential fired – MEA and MEP
01 01 01 15	Dry Bottom Tangential fired – MEA and HEP
01 01 01 16	Dry Bottom Tangential fired – HEA and NP
01 01 01 17	Dry Bottom Tangential fired – HEA and MEP
01 01 01 18	Dry Bottom Tangential fired – HEA and HEP

NA: no or low efficiency acidificant abatement systems
MEA: medium efficiency acidificant abatement systems
HEA: high efficiency acidificant abatement systems

NP: no or efficiency particles abatement systems
MEP: medium efficiency particles abatement systems
HEP: high efficiency particles abatement systems

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PM_{10} sources

- PM_{10} emissions in actual emission inventory activities in Italy only for existing SNAP codes or for SNAP codes for which also other pollutants are emitted
- only recently we introduce special sectors (brake, tires, and road abrasion in traffic sector, industrial storage, marine aereosol)
- a special regional program of Toscana Region will extend the classification and the inventory to other specific activities and review all the actually used emission factors

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Actual PM_{10} sources

	Sector	% total	% no point Sources
0202	Residential plants	35%	47%
0703	Heavy duty vehicles > 3.5 t and buses	8%	9%
0101	Public power	7%	
0303	Industrial combustion processes with contact	7%	2%
0406	Processes in wood, paper pulp, food, drink and others	5%	6%
0701	Passenger cars	4%	5%
0702	Light duty vehicles < 3.5 t	4%	6%
0806	Other mobile sources and machinery - Industry	4%	4%
0301	Industrial Combustion in boilers, gas turb. and stat. engines	4%	2%
1003	On-field burning of stubble, straw,...	3%	4%
0704	Mopeds and Motorcycles < 50 cm3	3%	4%
1103	Forest and other vegetation fires	3%	4%
0402	Processes in iron and steel industries and collieries	2%	
0808	Other mobile sources and machinery: Industry	2%	2%
0709	Traffic Road Abrasion	1%	2%

Relative contribution of sectors in four Italy regions

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Future PM_{10} sources ?

Sector	Number of specific activities
Mineral Products	27
Food and Agriculture	19
Chemical Manufacturing	18
Primary Metal Production	13
Pulp and Paper and Wood Products	7
Secondary Metal Production	6
Fabricated Metal Products	4
In-process Fuel Use	3
Cooling Tower	1
Unpaved Roads	1
Solid Waste Disposal – Commercial/Institutional	1
Solid Waste Disposal – Industrial	1

sectors with only PM_{10} emissions (source U.S. EPA Fire Database)

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Modeling PM_{10} emissions

- road transport sector
- domestic wood combustion
- marine aerosol (sea salt)

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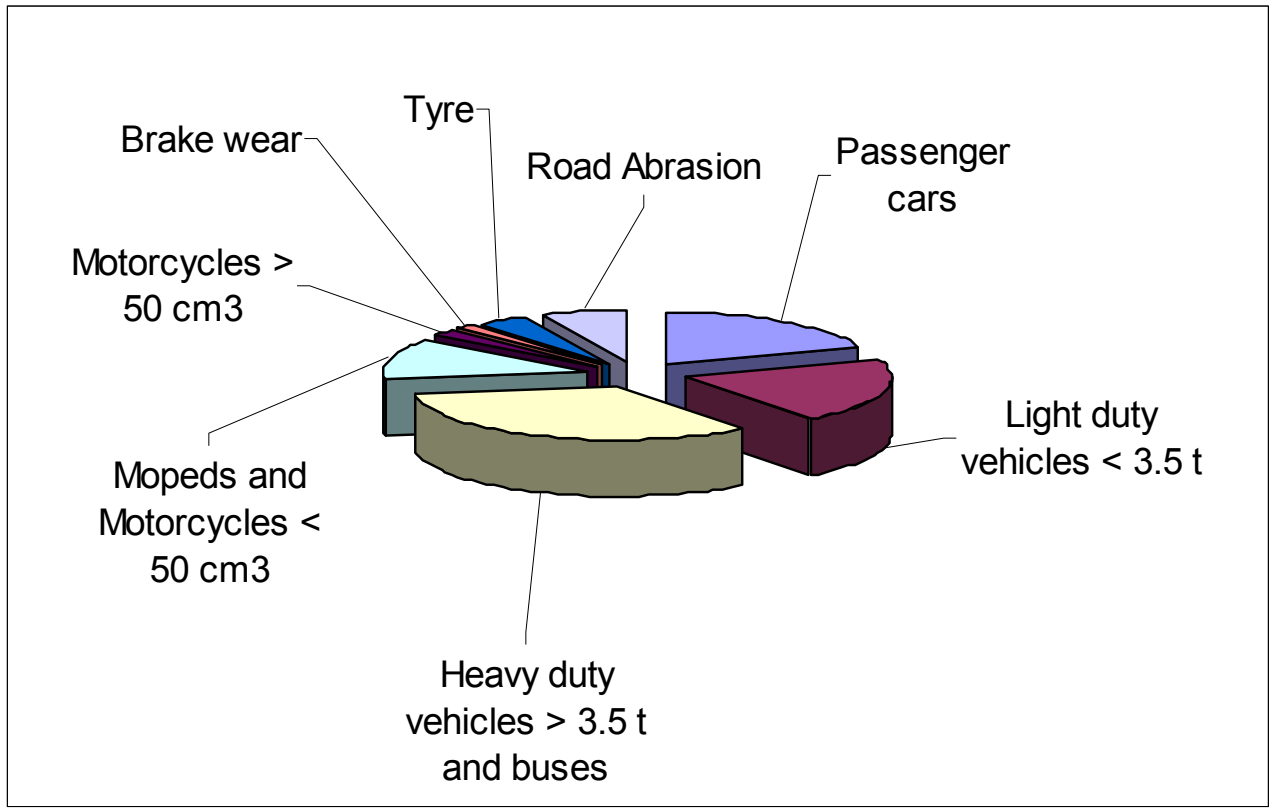
Road transport sector

computer model SETS has been updated to include gasoline vehicles emission, motorcycles emission and abrasion emission (brake, tires, and road abrasion)



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Domestic wood combustion

- in Italy, two recent statistic investigations by ENEA evaluated a consumption among 16 and 20 million of tons/year (>> official data) as more than half of firewood derives from private collect for personal consumptions
- this results, if validate, involves the revaluation of the estimates reported in the preceding chapter of around a factor six; in this case the combustion of the firewood represents of big long the principal source of emissions of PM_{10} in Italy

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Domestic wood combustion

- about 78% of the devices used in Italy is still at low technology, with a great prevalence of fireplaces and traditional heaters with low efficiencies
- finally we have experimented on municipal level a detailed methodology to evaluate wood consumptions from official census data on heating systems and direct data on gas consumptions; it is used now in the update procedure of regional inventories

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Dom. wood comb. E.F.

- a very good review work was recently concluded in ISPRA for small combustion installation in the frame EMEP/CORINAIR
- the values of 900 and 800 g/GJ of PM_{10} are proposed for fireplaces and domestic stoves using a lower heating value of 16 MJ/kg
- in Italy the national energy balance use a lower heating value of 10,5 MJ/kg
- as a results we obtain emission factors of 1.375 and 1.220 g/GJ of PM_{10} for fireplaces and domestic stoves in Italy

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Marine aerosol (sea salt)

- in Italy, and particularly in coastal areas, great relevance has been given to the contribution of sea aerosol
- a methodology validate at international level was preliminary evaluated in a special project for an Italy coastal area
- in the frame of the Tuscany regional program a full validation of the model through specific experimental sample of sea salt and the determination of specific Mediterranean parameters will be realized

C.Trozzi, R.Vaccaro, S.Crocetti, M.Pantaloni, C.Melis, A.Bernetti, D.Didero
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Marine aerosol: model

- we produce a first preliminary evaluation of concentrations, directly comparable with data of monitoring in the area
- sea-salt aerosol concentration (χ) is expressed as funcion of wind speed :

$$\chi = be^{aU10}$$

where U10 is the wind speed at 10 meter over sea level

- sperimental (in different locations) and model parameters (Gong et al model) were proposed

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Mar. aer. Model application

- the model was applied to the data for wind speed and compared with PM_{10} monitoring data
- two case was simulated, the first one with all wind direction, the second one with only wind direction incident the coast line
- the result show as it's very critical the choice of the parameters, particularly in coastal area where the turbulent motion of sea can increase the generation of sea salt

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carlo.trozzi@ techne-consulting.com

Marine aerosol: results

Wind direction		all	only coast incident
Kulkarni	Sea salt	12,49	9,57
Exton	Sea salt	23,19	19,04
Gras	Sea salt	3,54	3,04
Model	Sea salt	3,14	2,42
Experimental	Total PM_{10}	15,59	

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Uncertainty of emission inventories

- very importance was devoted in the last years at the determination and evaluation of the uncertainty in emission estimates
- the contest can be different in specific estimate (ex. for a point source) or sector estimate (traffic, vegetation, forest fires) from the evaluation in a national or regional inventory
- in some local emission inventories in Italy the general methodology proposed by US EPA EIIP and referred as DARS was introduced

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Uncertainty of emission inventories

- **local vs national**
  - **if an estimate is highly uncertain, but represents only 1% of total emissions, accurately quantifying the uncertainty is probably not a high priority**
  - **however, a source that is insignificant at a national level can be very important at a local level and high uncertainty in the estimated emissions may be unacceptable**
- **in some local emission inventories in Italy the general methodology proposed by US EPA EIIP and referred as DARS was introduced**

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EPA DARS Scheme

uncertainty is assigned to four aspect of activity and emission factors evaluation:

- **measurement/method of determination,**
- **source specificity**
- **spatial congruity**
- **temporal congruity**

Attribute	Factor	Activity	Emissions
Measurement/Method	e_1	a_1	$e_1 * a_1$
Source Specificity	e_2	a_2	$e_2 * a_2$
Spatial Congruity	e_3	a_3	$e_3 * a_3$
Temporal Congruity	e_4	a_4	$e_4 * a_4$
Composite			$[\Sigma_{i=1,4} (e_i * a_i)] / 4$

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EPA DARS Scheme Application

- As uncertainty is assigned to the single activities of the inventory, global uncertainty of group of activities or of the whole inventory can be computed as:

$$I_{ik} = \sum_{j \in k} E_{ij} I_{ij} / \sum_{j \in k} E_{ij}$$

where:

- I_{ik}, uncertainty of the emission of pollutant i from the group k,
- I_{ij}, uncertainty of the emission of pollutant i from the single activity j belonging to group k,
- E_{ij}, emission of pollutant i from the single activity j.

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Spatial Congruity example

Activity	Score
Activity data available to municipal (LAU 2) level	10
Activity data related to point or linear/nodal sources (traffic count, number of aircraft, number of ships)	10
Activity data available at provincial (NUTS 3) level with availability of proxy at municipal (LAU 2) level: proxy strongly correlated with activity	9
Activity data available at regional level (NUTS 2) with availability of proxy at provincial (NUTS 3) and municipal (LAU 2) level: proxy strongly correlated with activity	8
Activity data available at provincial (NUTS 3) level with availability of proxy at municipal (LAU 2) level: proxy weakly correlated with activity	7
Activity data available at regional level (NUTS 2) with availability of proxy at only municipal (LAU 2) level: proxy strongly correlated with activity	7
Activity data available at regional level (NUTS 2) with availability of proxy at provincial (NUTS 3) and municipal (LAU 2) level: proxy weakly correlated with activity	6
Activity data available at regional level (NUTS 2) with availability of proxy at only municipal (LAU 2) level: proxy weakly correlated with activity	5
Regional activity data unknown and evaluated from national total with availability of proxy to provincial and municipal (LAU 2) level	4
Regional activity data unknown and evaluated from national total with availability of proxy to municipal (LAU 2) level only	3

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Regional case study

Macrosectors	CO	COV	NO_x	PM_{10}	SO_X
Combustion in energy and transformation industries	8,18	7,33	9,80	8,69	9,90
Non-industrial combustion plants	7,18	6,94	6,58	7,17	7,06
Combustion in manufacturing industry	8,19	7,36	8,50	7,43	8,87
Production processes	7,75	6,76	8,35	7,09	8,95
Extraction and distribution of fossil fuels and geothermal energy		6,74			
Solvent and other product use		6,66		8,37	
Road transport	7,22	7,04	7,29	7,09	7,27
Other mobile sources and machinery	7,19	6,98	7,32	7,19	7,20
Waste treatment and disposal	7,57	7,75	8,80	7,28	8,54
Agriculture	6,45	6,65	6,45	6,25	
Other sources and sinks	6,60	6,00	6,60	6,45	
TOTAL	**7,26**	**6,78**	**7,88**	**7,28**	**9,65**

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Conclusion

- **Work are in progress to:**
  - define and use a more appropriate classification of activities (E-SNAP) at local level
  - focus on major sources of emission and validate the emission factors and methodologies for these sources
  - evaluated emissions in activities not actually covered in local inventories
  - evaluated uncertainty of local emission inventories

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