European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

2nd International Workshop *EuNetAir* on

New Sensing Technologies for Indoor and Outdoor Air Quality Control

Palazzo Nervegna-Granafei, Brindisi Municipality Headquarters

ENEA - Brindisi Research Center, Brindisi, Italy, 25 - 26 March 2014

Action Start date: 01/07/2012 - Action End date: 30/06/2016 - Year 2: 1 July 2013 - 30 June 2014

Development of a Portable Sensor-System for Air Quality Monitoring

Domenico SURIANO, Michele PENZA

ENEA - Brindisi, Italy

OUTLINE

- **STATE-OF-ART ON AQ SENSING TECHNOLOGIES:**
  - **Data Quality Objectives (DQO) of AQ DIRECTIVE (2008/50/EC) on Ambient Air Quality and Cleaner Air for Europe (CAFE)**
- **VALIDATED AQ MONITORING by ENEA NASUS SENSORS:**
  - **CO Monitoring in collaboration with ARPA-Puglia, Brindisi, IT**
  - **NO_2, PM_{10} Monitoring in collaboration with JRC-IES, Ispra, IT**
- **CURRENT CHALLENGES:**
  - **AQ Sensors Applications in City of Bari: IT PON *RES-NOVAE***
  - **IAQ Sensors Applications in Schools: IT PON *BAITAH***
  - **AQ Sensors Applications on Buses (L'Aquila): IT *Smart Ring***
- **CONCLUDING REMARKS:**
  - **IAQ and AQ Sensors Applications in European Cities (!?)**

CURRENT STATUS in AIR QUALITY SENSORS

European Commission

Michel Gerboles, JRC-Ispra, IES

Fixed measurements: definition

'fixed measurements' means measurements taken at fixed sites to determine the levels in accordance with the relevant *Data Quality Objectives* (DQO);

Fixed measurements are mandatory in zones and agglomerations where the upper assessment thresholds are exceeded.

AQD: European DIRECTIVE 2008/50/EC on ambient air quality and cleaner air for Europe, art. 2

CURRENT STATUS in AIR QUALITY SENSORS

European Commission

Michel Gerboles, JRC-Ispra, IES

AQD: Data Quality Objectives (DQO)

	SO_2, NO_2/NOx, CO	**Benzene**	**O_3**
Uncertainty for **fixed measurements**	15 %	25 %	15 %
	Fluoresc., chemil., NDIR	automatic GC or pumped sampling	UV photometry
	demonstration of equivalence would be mandatory to use micro-sensors		

CURRENT STATUS in AIR QUALITY SENSORS

European Commission

Indicative methods: definition

'indicative measurements' means measurements which meet *data quality objectives* that are less strict than those required for *fixed measurements*;

AQD: European Directive 2008/50/EC on ambient air quality and cleaner air for Europe, art. 2

Michel Gerboles, JRC-Ispra, IES

CURRENT STATUS in AIR QUALITY SENSORS

European Commission

AQD: Data Quality Objectives (DQO)

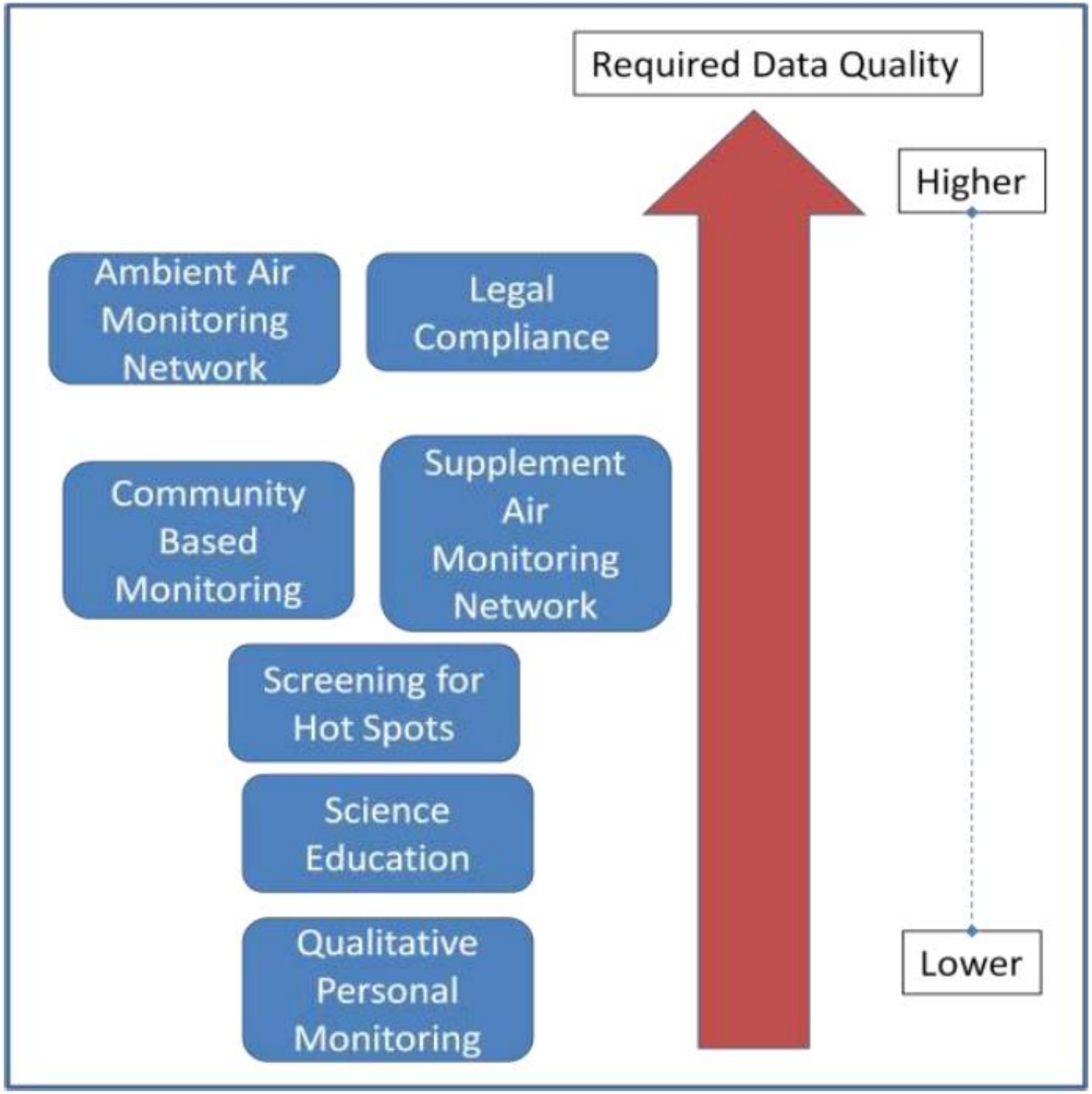
	SO_2, NO_2/NO /NOx, CO	Benzene	O_3
Uncertainty for **fixed measurements**	15 %	25 %	15 %
Uncertainty for **indicative measurements**	**25 %**	**30 %**	**30 %**
	diffusive samplers, ***micro-sensors***		

Michel Gerboles, JRC-Ispra, IES

Roadmap for Next Generation Air Monitoring

U.S. Environmental Protection Agency

Data Quality Requirements for the range of NGAM applications



US EPA, March 2013:

Tim Watkins, US EPA
Watkins.Tim@epa.gov

Viens Matthew, US EPA
Viens.Matthew@epa.gov

http://epa.gov/research/airscience/docs/roadmap-20130308.pdf

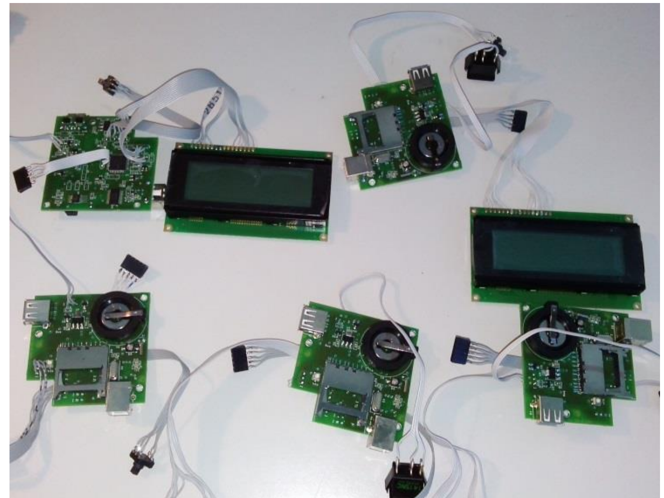
PORTABLE AQ SENSOR-SYSTEM: ENEA NASUS

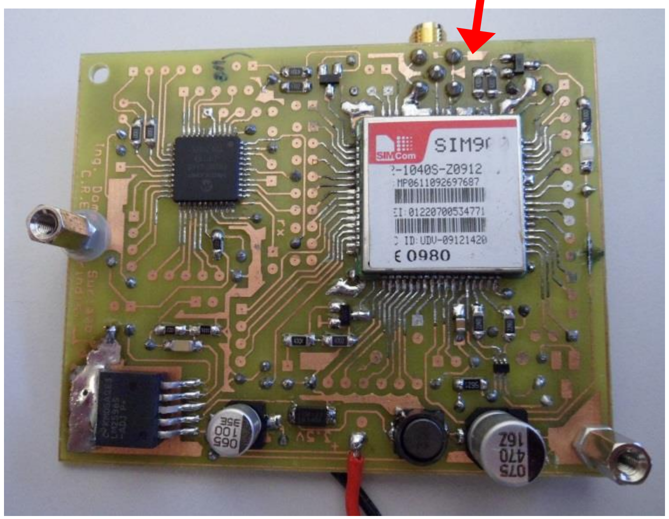
- **TECHNICAL DATASHEET**
- **AQ SENSORS: CO, NO_2, SO_2, H_2S, PM_{10}, RH, T**

NASUS 4: an hand-held sensing device building attempt (1/2)

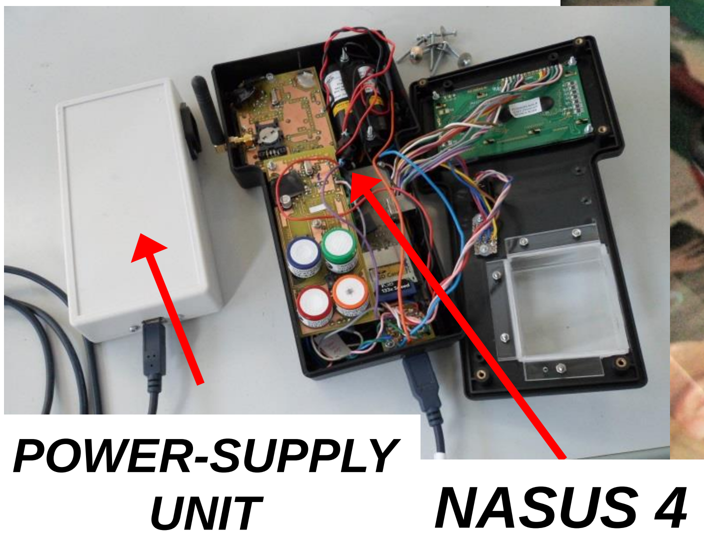
NASUS 4 Modular Design:

- Motherboard Module
- EC Gas Sensors Module
- Wireless Module (GSM)
- Power Module





NASUS 4: an and-held sensing device building attempt (2/2)



- **hand-held device**
- **average power consumption: 0.15W**
- **average battery autonomy: 46hrs**
- **fully remote operated by GPRS-GSM networks**
- **real time monitoring**
- **4 electrochemical gas sensors onboard + Temperature + RH (sensors)**
- **solar-cells automatic power switching (smart power management)**

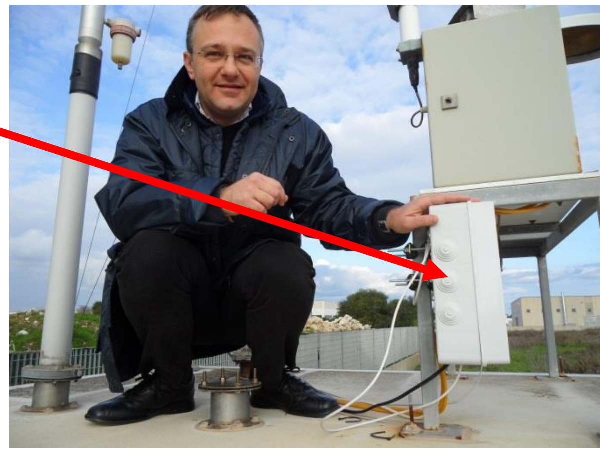
VALIDATED AQ MONITORING by ENEA NASUS SENSORS:

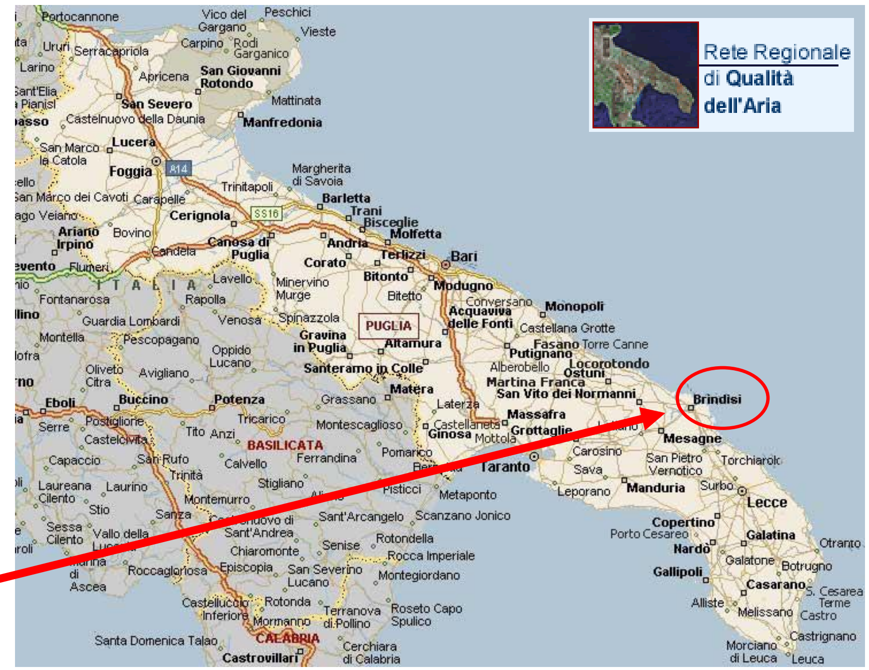
- CO Monitoring in collaboration with ARPA-Puglia, Brindisi, IT
- NO_2, PM_{10} Monitoring in collaboration with JRC-IES, Ispra, IT

NASUS 4: VALIDATION in Collaboration with ARPA-Puglia (1/4)

VALIDATION OF *NASUS 4* IN AN OFFICIAL LOCAL-NODE OF THE NETWORK <u>ARPA-PUGLIA</u>, *Regional Agency for Environmental Protection*

Nasus 4 on ARPA PUGLIA fixed station roof





ARPA-PUGLIA fixed stations locations: Industrial area at Brindisi (Italy)

NASUS 4: VALIDATION in Collaboration with ARPA-Puglia (2/4)

Validation Time-Domain Measurements Method:

NASUS 4 Sensors *versus* Standard Chemical Analyzers

Standard Chemical Analyzers

VS

NASUS 4 Sensors by ENEA Brindisi

NASUS 4: CO Validation in Collaboration with ARPA-Puglia (3/4)

$E(t) = |C_N(t) - C_A(t)|$

Mean E(t) = 28.6 ppb

Max E(t) = 339.5 ppb

E(t) = Error

$C_N(t)$: Nasus 4 CO sensor concentration

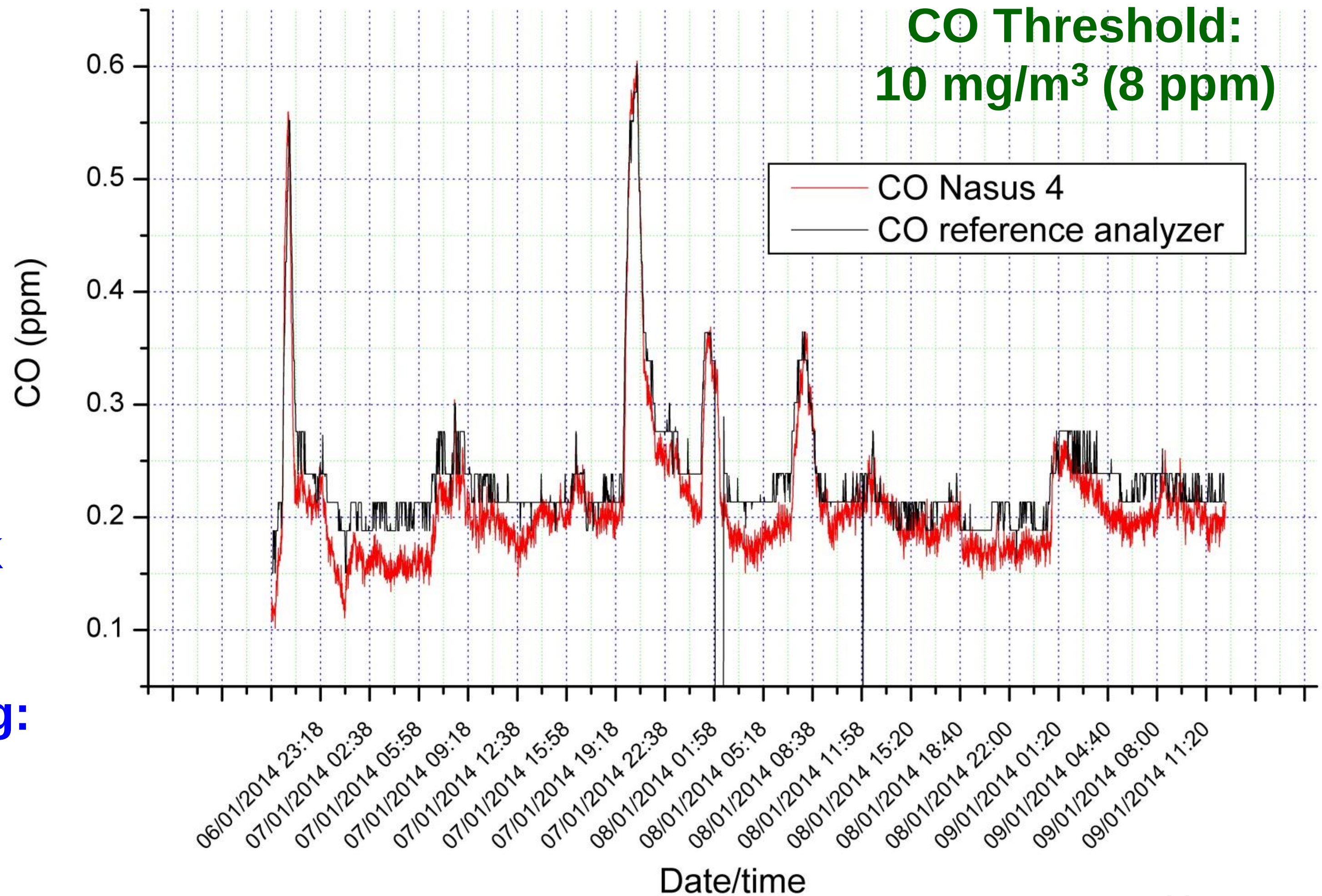
$C_A(t)$: CO reference analyzer concentration

Very Good Accuracy !

CO EC Sensor COCX by Alphasense Ltd, UK

Measurement Timing: 6 - 9 January 2014

CO Threshold: 10 mg/m³ (8 ppm)



EUROPEAN COOPEI

NASUS 4: CO Validation in Collaboration with ARPA-Puglia (4/4)

$E(t) = |C_N(t) - C_A(t)|$

Mean E(t) = 29.05 ppb

Max E(t) = 427.6 ppb

Very Good Accuracy !

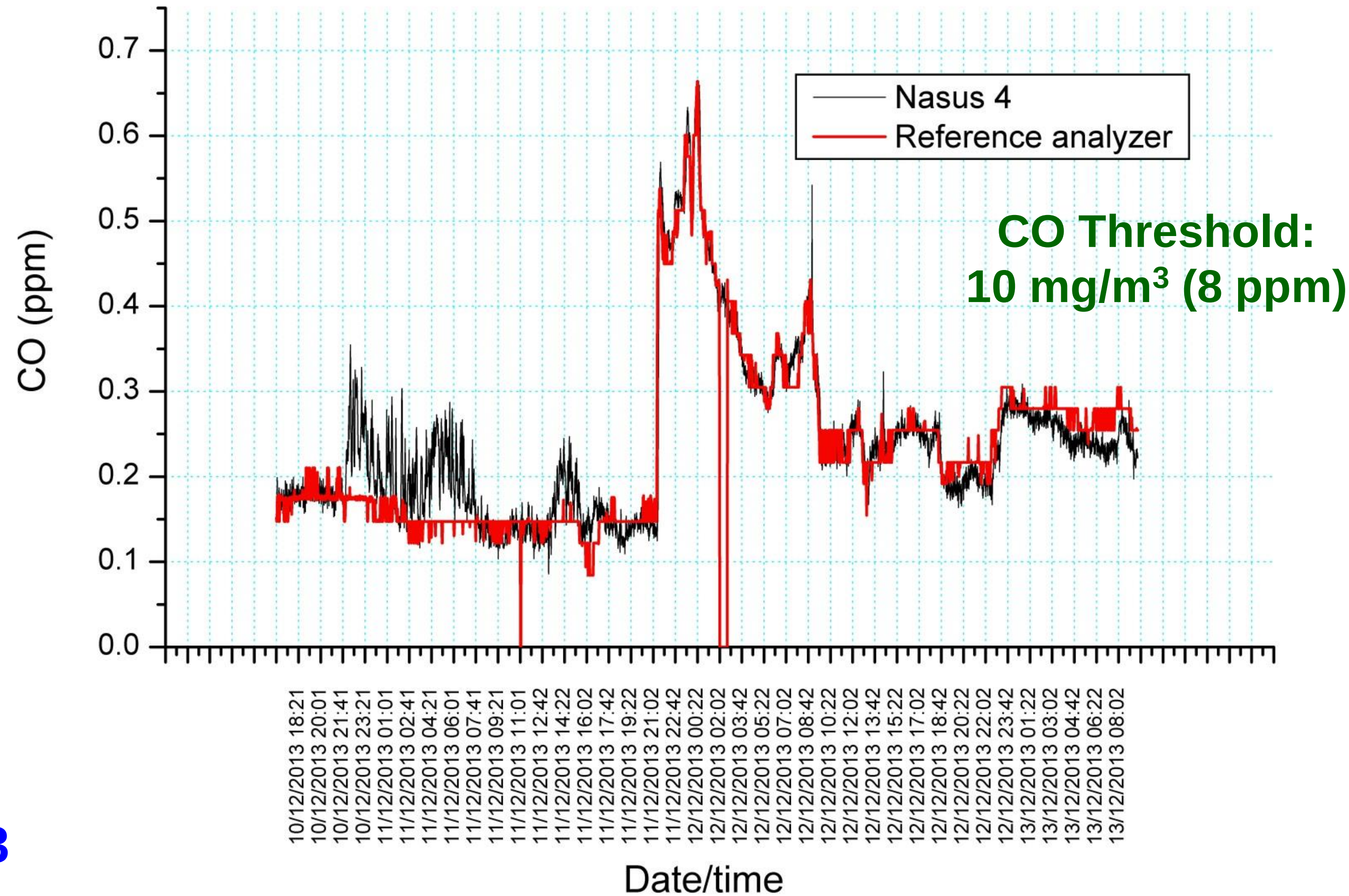
CO EC Sensor COCX by Alphasense Ltd, UK

Measurement Timing: 10 - 13 December 2013

E(t) = Error

$C_N(t)$: Nasus 4 CO sensor concentration

$C_A(t)$: CO reference analyzer concentration



VALIDATION OF *NASUS 4* IN A REAL SCENARIO
BY MEANS OF JRC AQ MOBILE LAB

NASUS 4 on JRC AQ Mobile Laboratory

NASUS 4: Validation in Collaboration with JRC-IES, Ispra (2/6)

Validation Time-Domain Measurements Method:

NASUS 4 Sensors *versus* Standard Chemical Analyzers

Standard Chemical Analyzers

VS

NASUS 4 Sensors by ENEA Brindisi

NASUS 4: NO_2 Validation in Collaboration with JRC-IES, Ispra (3/6)

$E(t) = |C_N(t) - C_A(t)|$

Mean E(t) = 5 ppb

Max E(t) = 12.7 ppb

Very Good Accuracy !

NO_2 Thresholds:
200 μg/m³ (100 ppb)
400 μg/m³ (200 ppb)

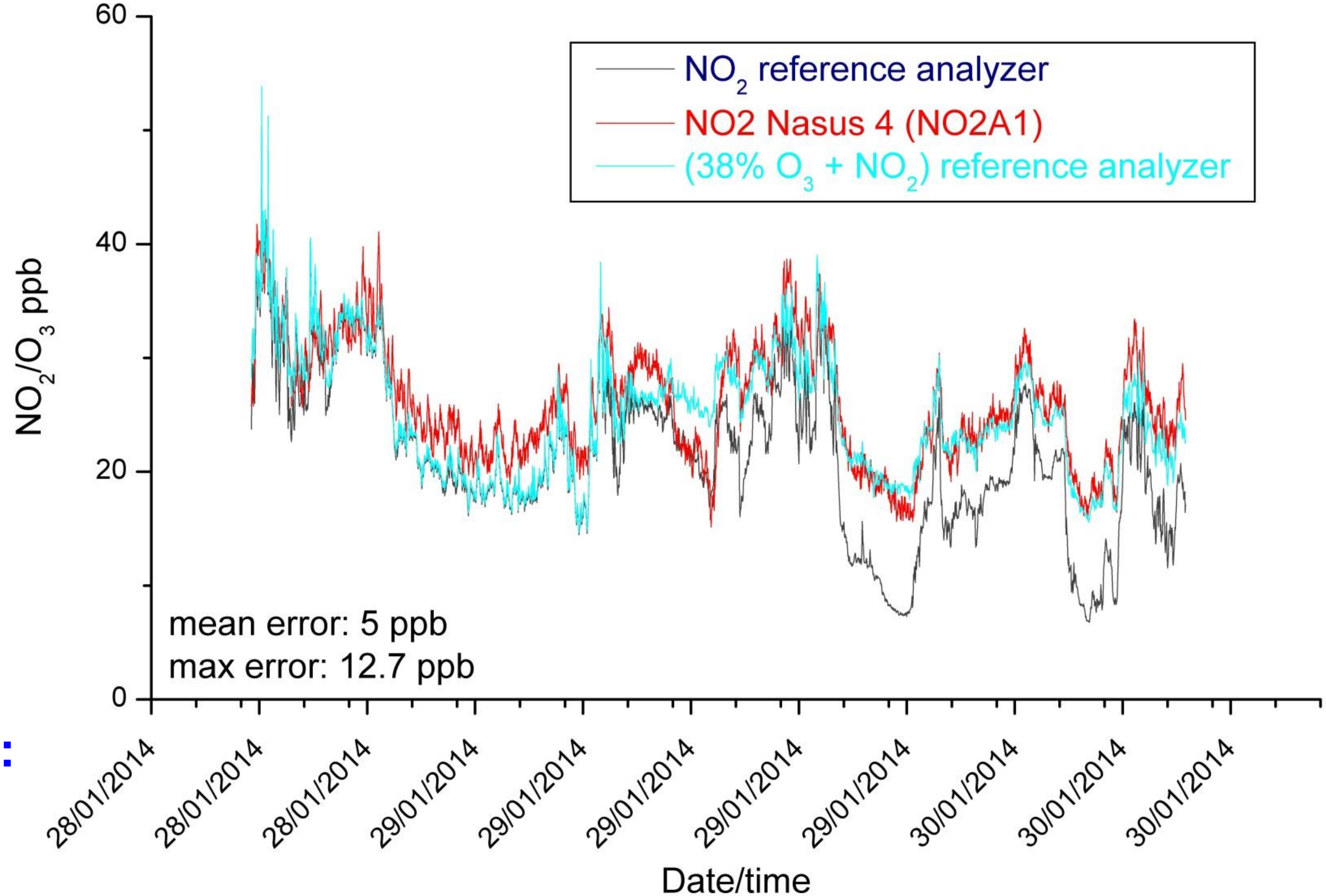
NO_2 EC Sensor NO2A1 by Alphasense Ltd, UK

Measurement Timing: 28 - 30 January 2014

E(t) = Error

$C_N(t)$: Nasus 4 NO_2 sensor concentration

$C_A(t)$: NO_2 reference analyzer concentration



NASUS 4: NO_2 Validation in Collaboration with JRC-IES, Ispra (4/6)

$E(t) = |C_N(t) - C_A(t)|$

Mean E(t) = 3.36 ppb

Max E(t) = 14.83 ppb

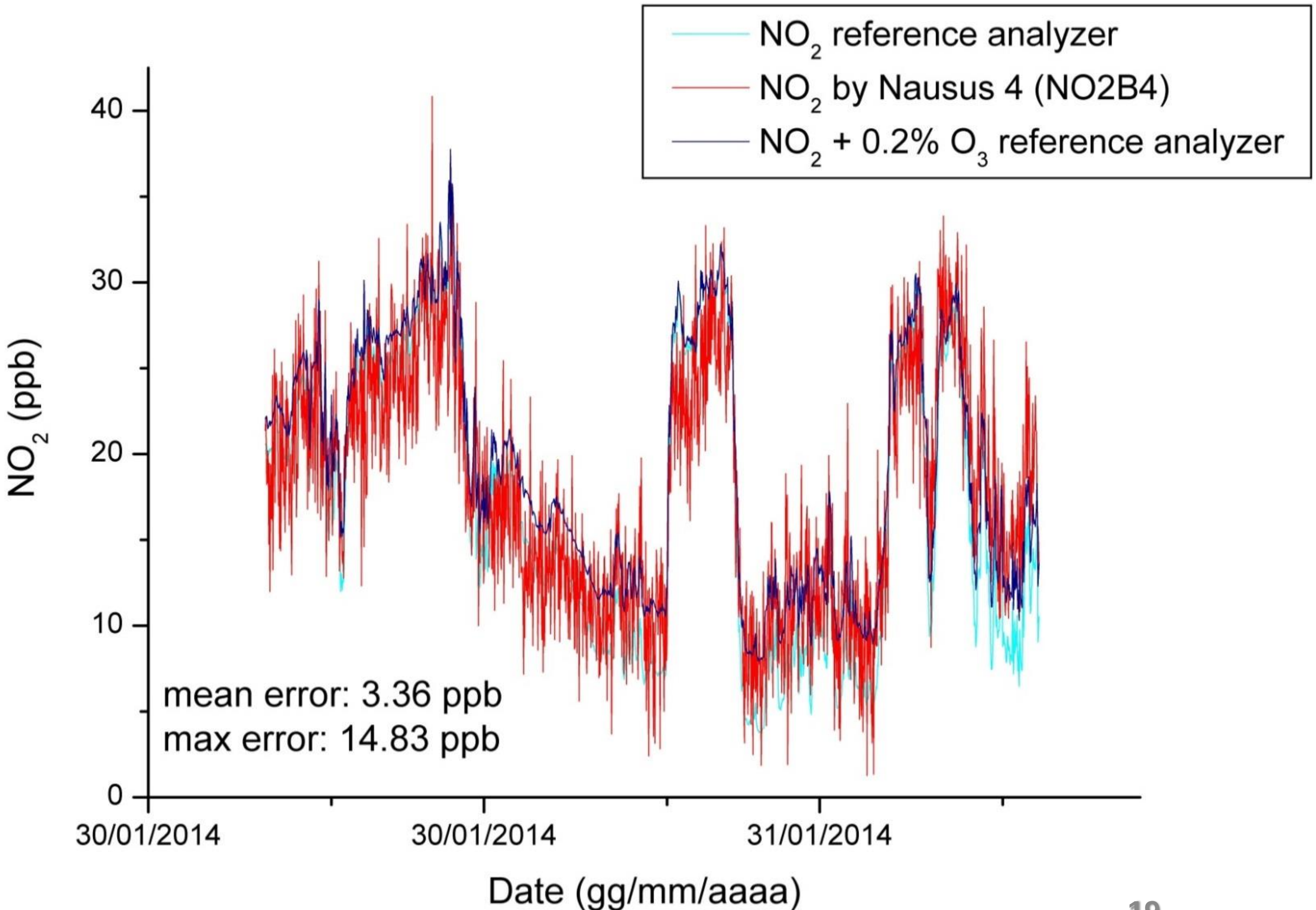
E(t) = Error

$C_N(t)$: Nasus 4 NO_2 sensor concentration

$C_A(t)$: NO_2 reference analyzer concentration

Very Good Accuracy !

NO_2 Thresholds:
200 $\mu g/m^3$ (100 ppb)
400 $\mu g/m^3$ (200 ppb)



NO_2 EC Sensor NO2B4 by Alphasense Ltd, UK

Measurement Timing: 30 - 31 January 2014

cost EUROPEAN COC

NASUS 4: PM Validation in Collaboration with JRC-IES, Ispra (5/6)

PPD20V Particle Sensor
by Shinyei Ltd, Japan

Detectable Particle Size: 1 - 5 μm

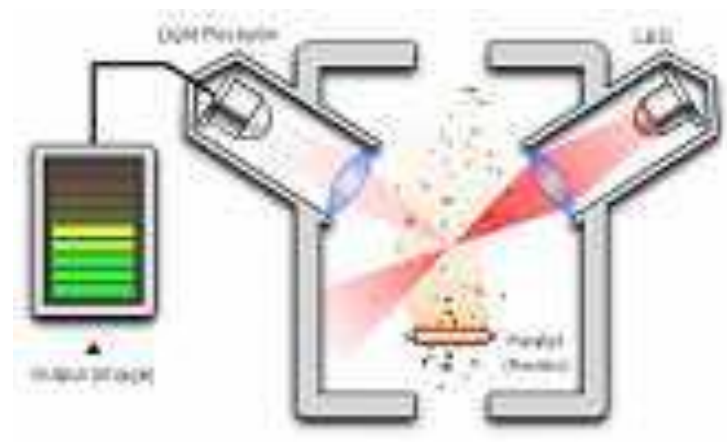
$$C(t) = A_0 + S \times V(t)$$

C(t) = PM Concentration [μg/m³]

A_0 = Bias Constant (3.2795 μg/m³)

S = Sensor Sensitivity (46.85 (μg/m³)/V)

V(t) = Sensor Output Voltage [V]



NASUS 4: PM Validation in Collaboration with JRC-IES, Ispra (6/6)

$E(t) = |C_N(t) - C_A(t)|$

Mean E(t) = 8.98 μg/m³

Max E(t) = 41.76 μg/m³

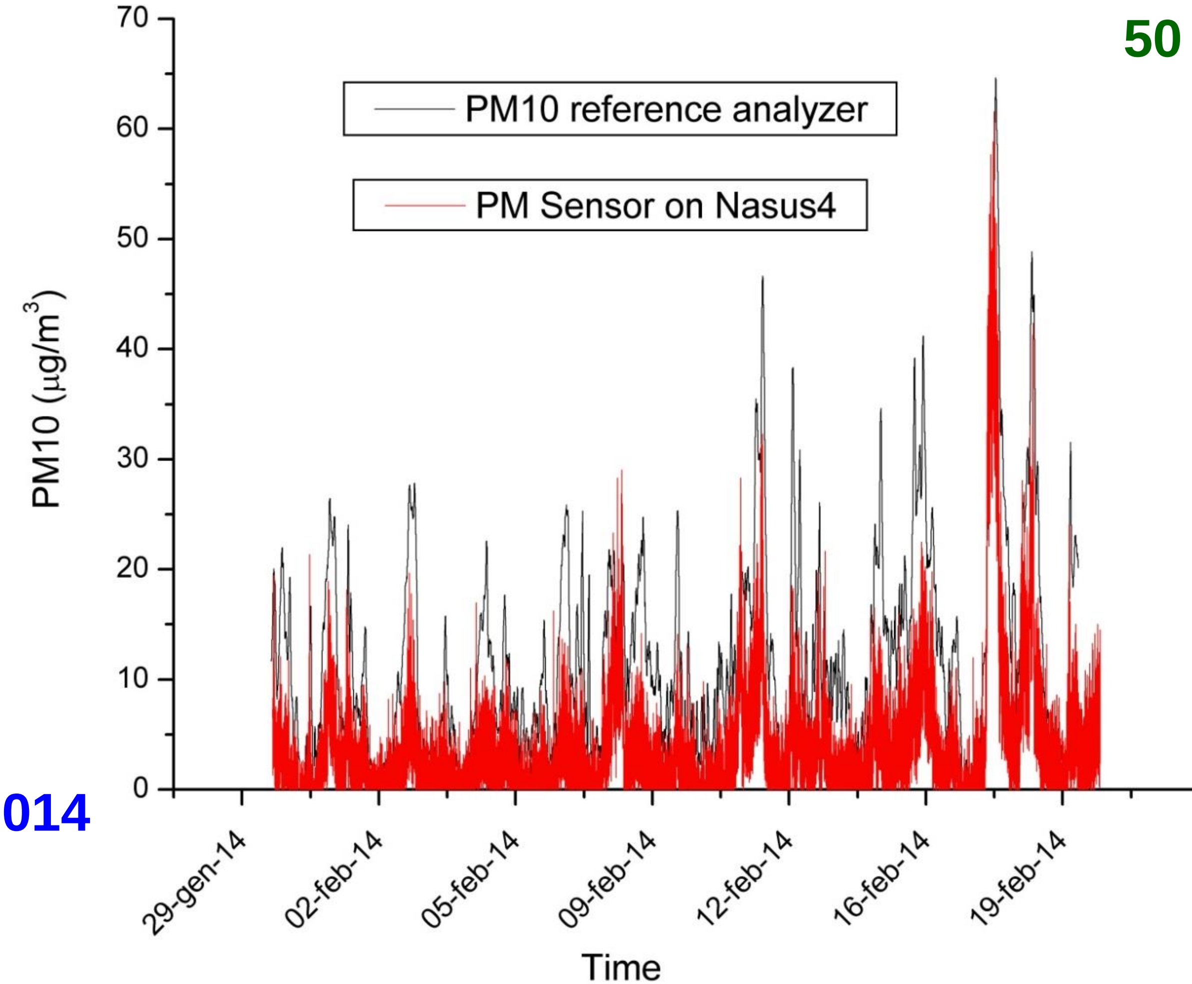
E(t) = Error

$C_N(t)$: NASUS 4 PM sensor concentration

$C_A(t)$: PM10 reference analyzer concentration

Very Good Accuracy !

PM10 Threshold: 50 μg/m³



Optical Particle Sensor PPD20V by Shinyei Ltd, Japan

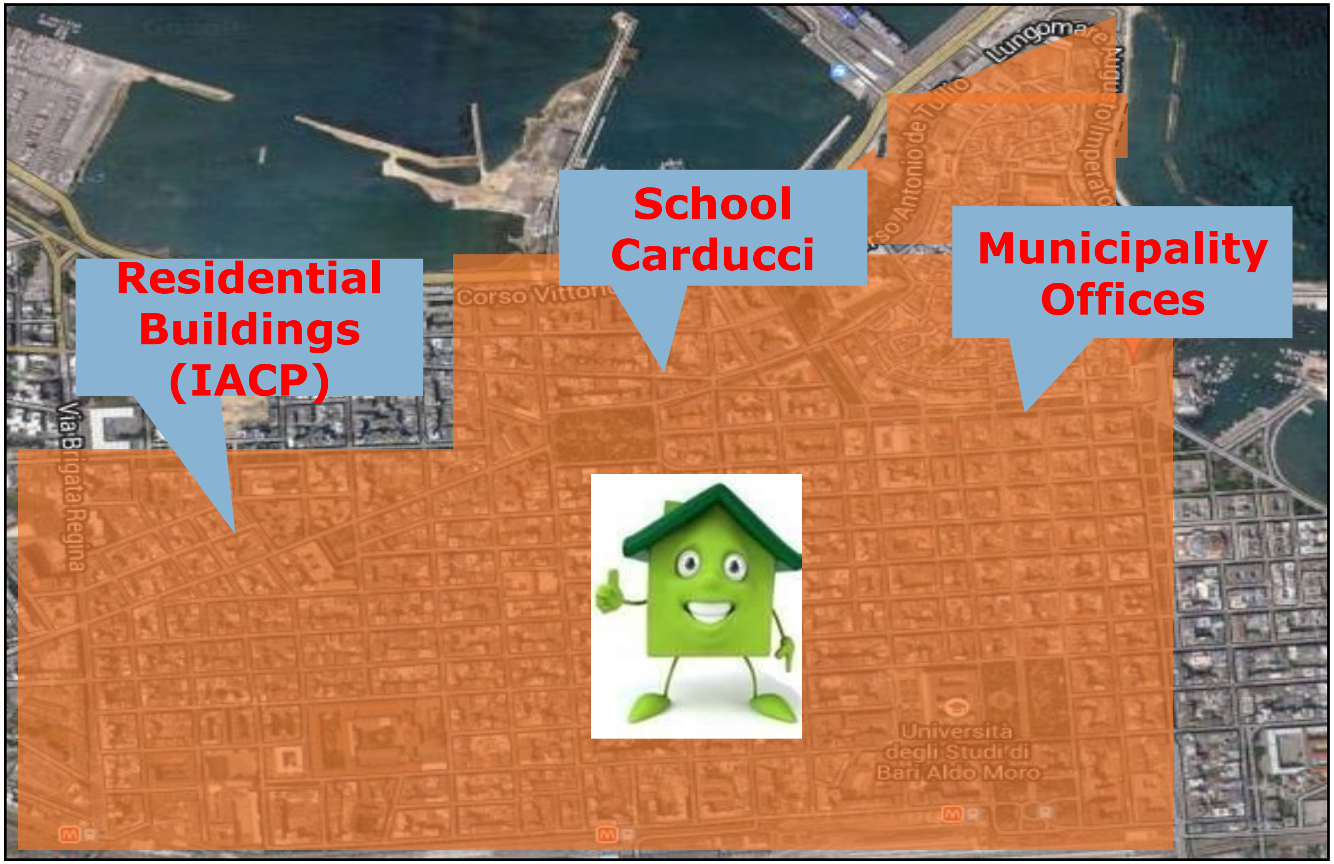
Measurement Timing: 29 Jan 2014 - 19 Feb 2014

cost EUROPEAN CO

VIDEOCLIP *NASUS*: CARS AIR-EXHAUST

IT NATIONAL PROJECT *RES-NOVAE*: INDOOR APPLICATIONS

Smart City Bari



ENEA AQ Sensor Node

Real-Word Scenario for Sensor Technology Demonstration:
Schools, Public Offices, Buildings

IT NATIONAL PROJECT *RES-NOVAE*: OUTDOOR APPLICATIONS

Real-Word Scenario for Sensor Technology Demonstration:
AQ ENEA Sensors Fixed Nodes Network distributed in Bari (Italy)
Urban Control Center (UCC) collects ENV/ENE/OTH data from City.

Smart City Bari

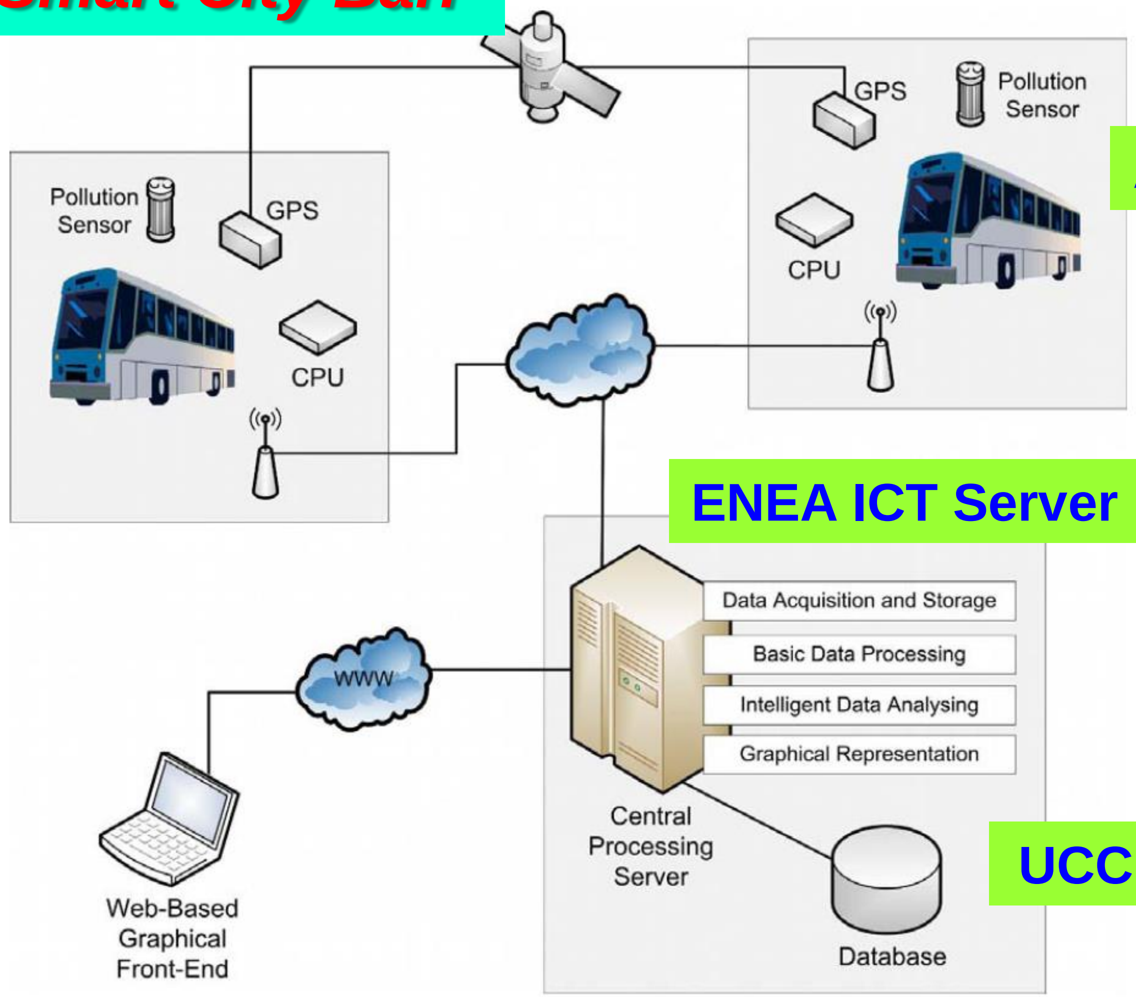
IT NATIONAL PROJECT *RES-NOVAE*: OUTDOOR APPLICATIONS

Real-Word Scenario for Sensor Technology Demonstration:

AQ ENEA Sensors Mobile Node mounted on public bus (AMTAB) in Bari (Italy).

Urban Control Center (UCC) collects ENV/ENE/OTH data from City.

Smart City Bari



AMTAB Public Buses

ENEA ICT Server

ENEA Mobile Sensor Node for Air Quality Monitoring: CO, NO_x, O_3, SO_2, CO_2, PM10, T, RH

UCC by IBM Italia

CONCLUSIONS and Future Activities

- **Low-cost Micro-sensors should not substitute but supplement routine monitoring devices, at the moment**.
- Use of **portable systems** based on ***low-cost solid-state gas sensors*** to supplement high-cost standard chemical analyzers should be possible for some pollutant gases.
- Further **long-term investigations** in order to extend the range of air-pollutants detectable by ***low-cost solid-state gas sensors*** at higher accuracy.
- Further **sensor-system miniaturization and integration** with commercial electronics (e.g., smartphones, tablets, etc.) for **community participatory environmental sensing**.
- **Air Quality Control Fixed/Mobile Sensors Network for Smart Cities Applications**.

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ON AQ SENSORS VALIDATION

ARPA PUGLIA

ENEA:

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Mariagabriella VILLANI, ENEA - Ispra, Italy

ENEA
AGENZIA NAZIONALE
PER LE NUOVE TECNOLOGIE, L'ENERGIA
E LO SVILUPPO ECONOMICO SOSTENIBILE

cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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- **CONSORTIUM COST Action TD1105 EuNetAir**

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

- **PON1 BAITAH:**

Methodology and Instruments of Building Automation and Information Technology for pervasive models of treatment and Aids for domestic Healthcare

BAITAH

- **PON4a RES-NOVAE:**

Networks, Buildings, Streets - New Challenging Targets for Environment and Energy

RES NOVAE

Reti Edifici Strade Nuovi Obiettivi Virtuosi per l'Ambiente e l'Energia

Any Questions ?

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