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INSPIRE 2018
Antwerp

Development of a national Spatial Data Infrastructure for Open Sensor Data based on citizen science initiatives

L. Carton[1], J. van den Broecke[2,3], M.Grothe[2], J. Hoeks[4] ; R.Kieboom[5] ; P.Geurts[6], J. van der Heide[7], H.Volten[8], H. Nijhuis[6], P. van der Voorn[6], H. Nouwens[9], E. van der Zee[10]; M.Jacobs[11], P. Biemans[11]

[1]Radboud University, Institute for Management Research, [2]Geonovum, [3]Just Objects, [4]Intemo, [5]CityGIS, [6]Municipality Nijmegen, [7]Kadaster (Netherlands), [8]National Institute for Public Health and Environment (RIVM), [9] Smart Data City, [10]Geodan, [11]representative citizen scientists, working group of citizen sensor holders in Nijmegen

INSPIRE 2018, 20 September, Antwerp. Track Environmental monitoring and reporting - 20/09/2018 - 16:00, room: Okapi 2.

Content of presentation

- **Introduction:** Relevance
- A Dutch pilot as case study, **Smart Emission**: Development of data chain and sensor data processing infrastructure, with citizens as end-users, in a city (Nijmegen)
  - Developed, description of parts of the **sensor data infrastructure** as built for Smart Emission
  - Use of the sensor data infrastructure: illustrations with citizen science use cases

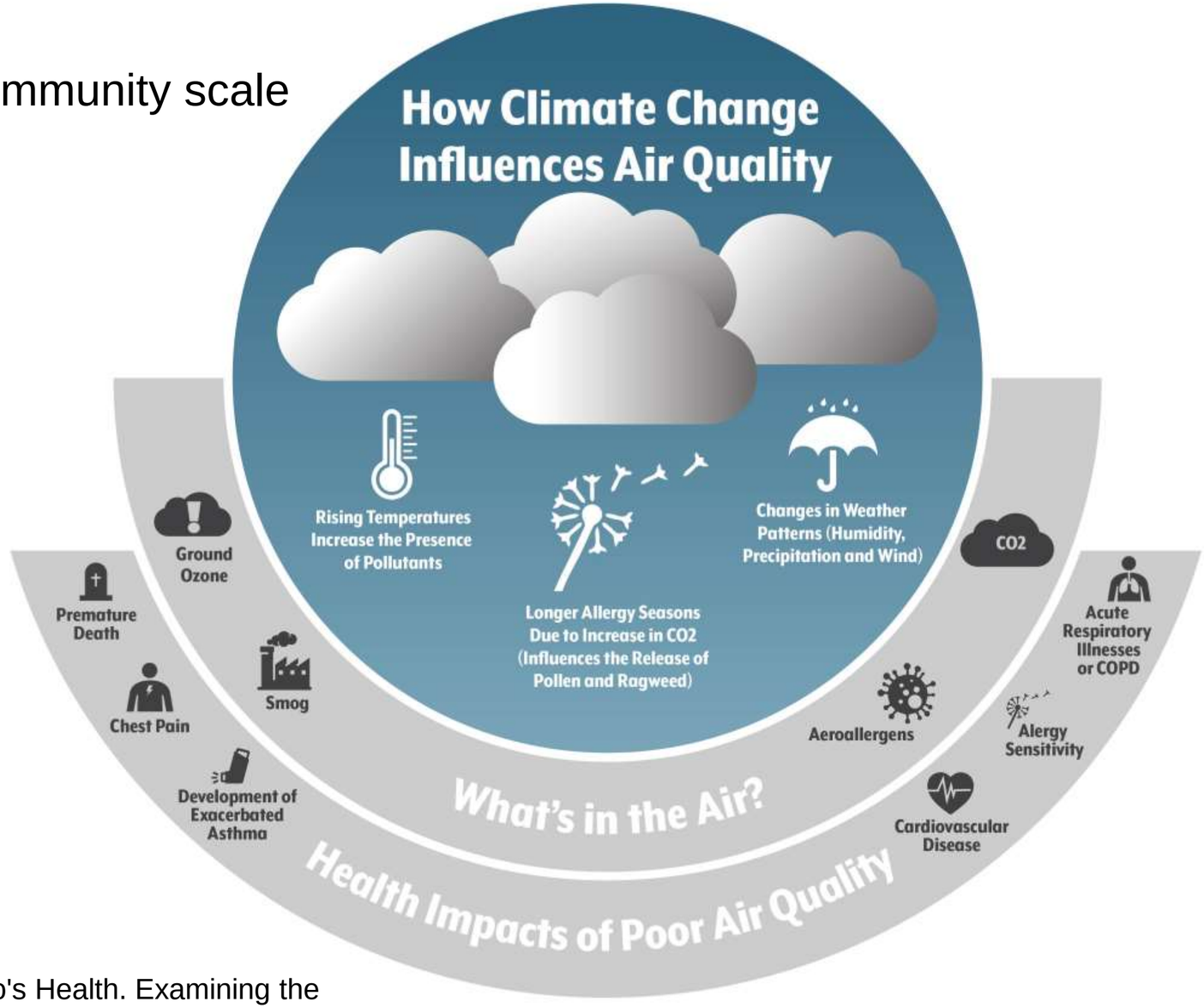
    (including screendumps of the sensor data platform)
- **Conclusion:**
  - *Message: Discussion on needs, (dis-) advantages and implications*
  - *Idea to establish a public spatial data infrastructure for small sensor data*
  - *Include small sensors of citizen initiatives, for fine-grained measurement of environmental indicators (ozone, NO2, PM10, PM2,5, noise, temperature, etc.)*

Relevance: Aggraveted bad air quality expected under changing climate conditions

Feedback loops between:

1. **Air Quality** on urban scale
2. **Human Health** on individual/group/ community scale
3. **Climate Change** on global scale

Photo: Voice of America
A small-particle haze hangs above the skyline of **Paris**, France, Dec. 1, 2016.



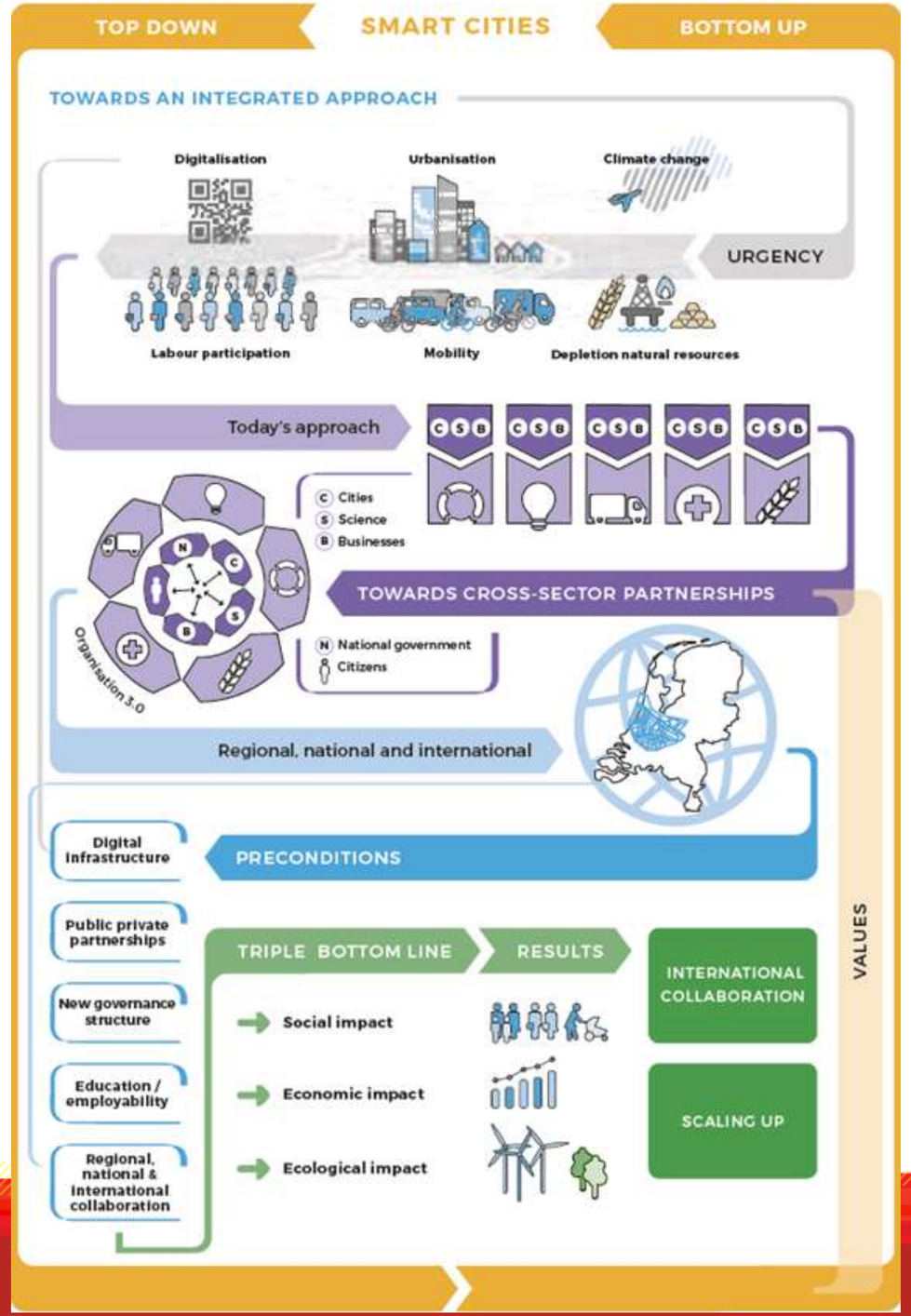
Source infographic:
Report (2017) Colorado's Climate and Colorado's Health. Examining the Connection. Colorado Health Institute

Smart cities, a national strategy document

Smart City strategy-making process in the Netherlands, a private-public initiative;
amongst others supported by Alliander (Utility, energy infrastructure), National Smart City Living Lab, and many others business and societal partners…

Key terms:
- Digital Infrastructure
- Cross-sector partnerships
- New governance models

Report: https://gsc3.city/wp-content/uploads/NL_Smart_City_Strategie_EN_LR.pdf



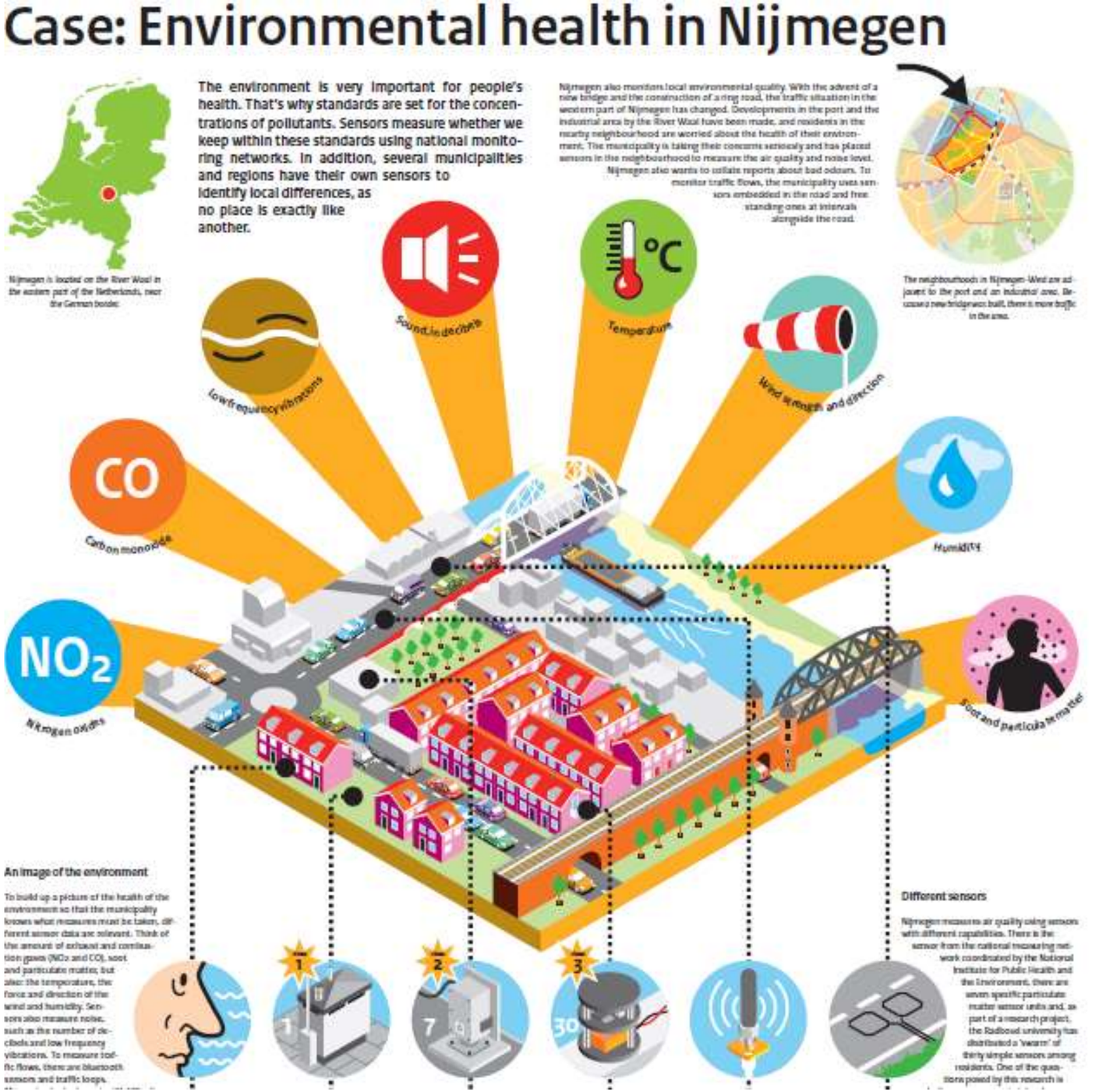
Smart Emission Pilot

2015 -2017, city of Nijmegen

One of the citizen science initiatives in the Netherlands on monitoring air quality and noise, in near-realtime

Research questions:

1. Do low-cost sensors add to the fine-grained picture of air quality indicators?
2. **Does the concept work?**
3. Does sense-making with citizens work?
4. Does this open up opportunities for environmentally-informed city governance?
5. Reflective: (How) do roles of government and citizen change?



Smart Emission pilot project (2015 – 2017) innovate with citizen science and new small sensors, let citizen join in monitoring environmental externalities of the city

FIWARE Lab NL
Data & Tools
Partner voor de smart city

STW
Enabling new technology

maps4society

Making Sense
for Society
Living Lab for the Internet of Everything

Core concept Smart Emission project:

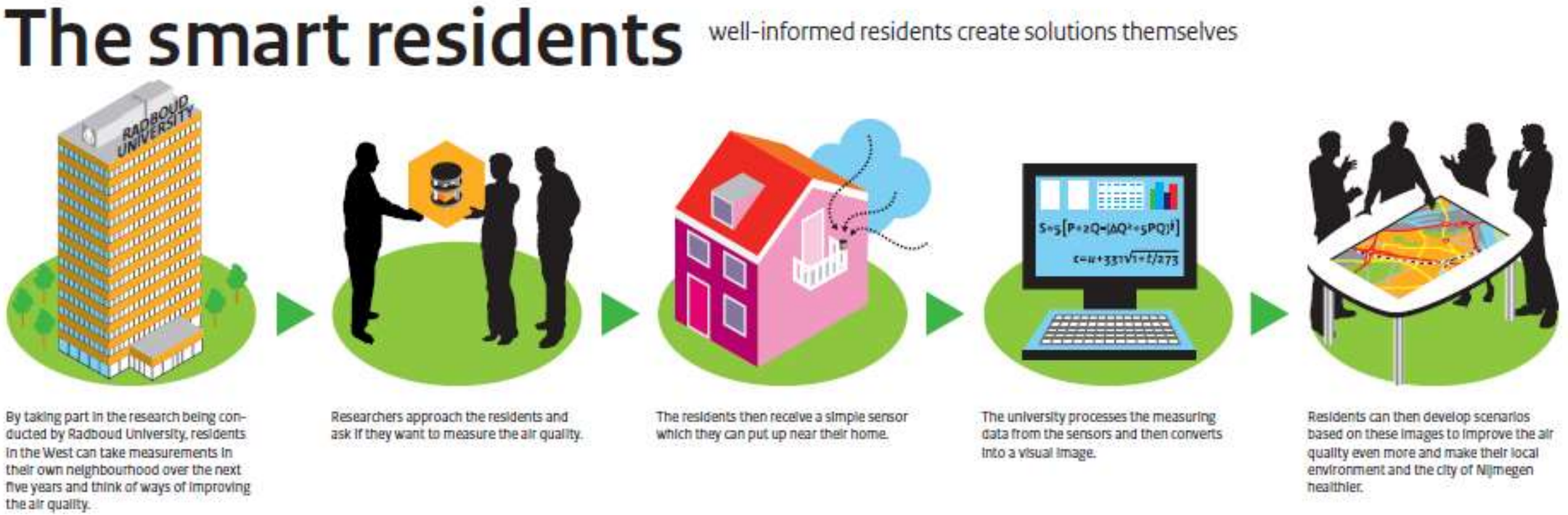
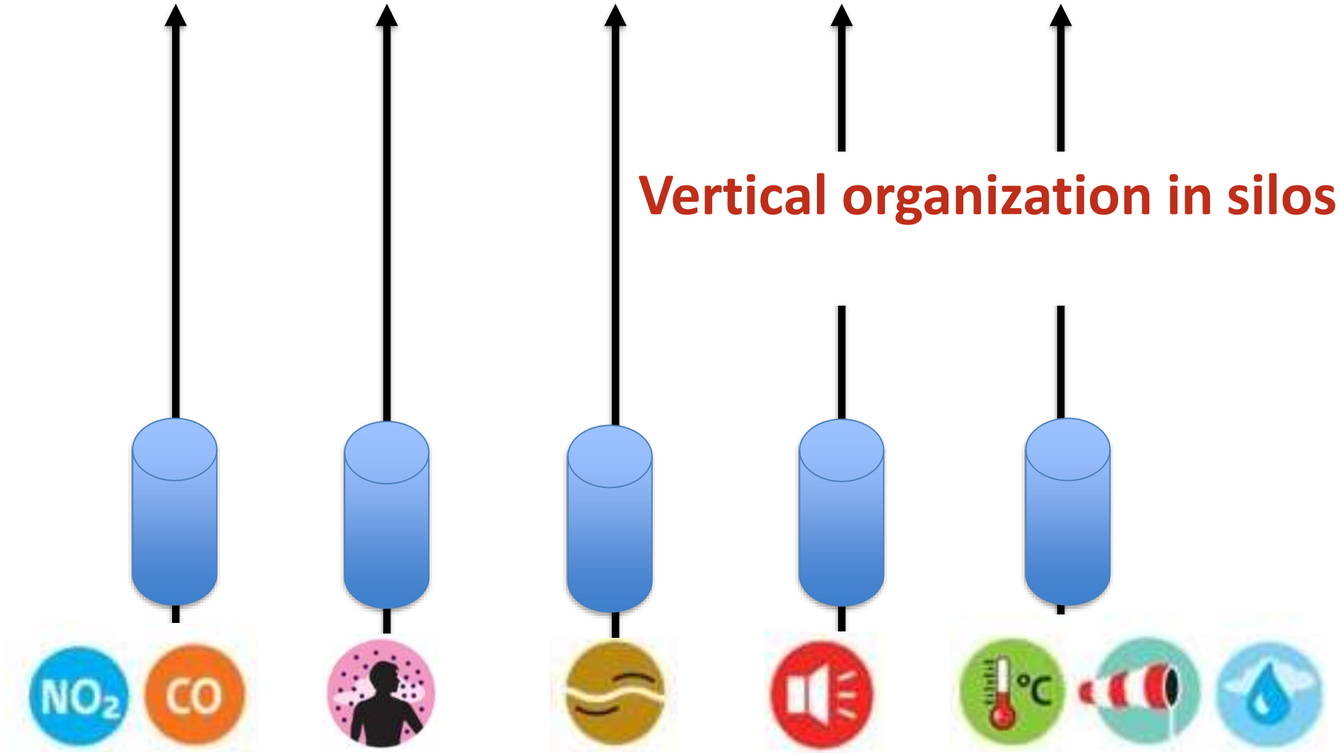


Illustration: Anke Nobel

Consortium Smart Emission: Radboud University, Municipality Nijmegen, Intemo, CityGIS, Geonovum, RIVM, and 34 citizen-sensor-holders in the city of Nijmegen. Students helped in exploring the data, making visualisations, and interviewing the citizens on their perspective.

Current practice in many app developments, organized in silos

Sensor equipment has been developed for analyzing a dedicated, disciplinary phenomenon



Idea:

Janus Hoeks, Intemo:

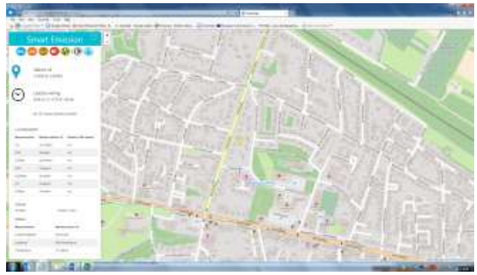
Specialize in maintaining small sensor stations in a cost-effective, efficient manner, optimizing distance-maintenance.

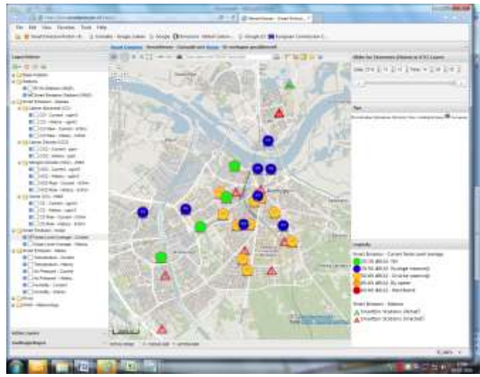
Coordinate the knowledge and the data chain in:

- Sensor management and maintenance
- Data management
- Sensing-specific data analytics, (automated) information analysis
- Publishing for viewing and interpreting by experts and citizens

From vertical to horizontal sensing

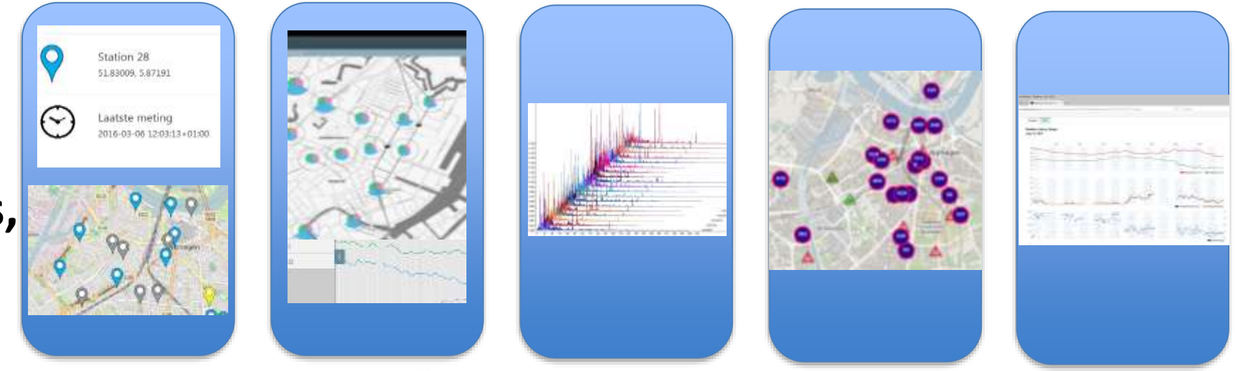
Integrated viewers





Instead of silo solutions for every sensing sector…

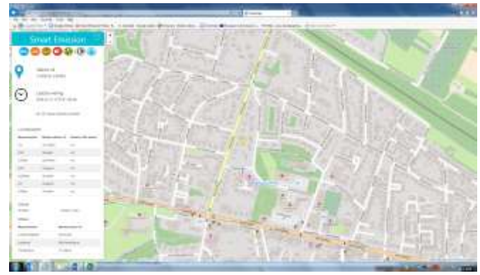
create integral sensor stations, data chain processing, and publishing

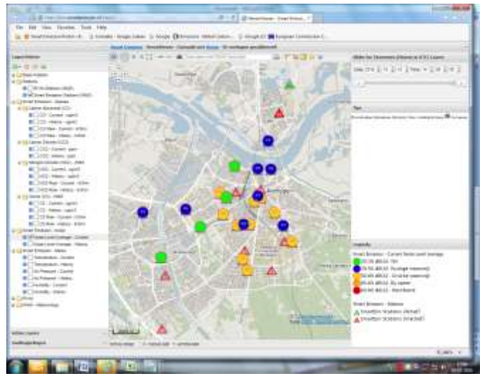


App 1 App 2 App 3 App 4 App 5

Integrated viewers

From vertical to horizontal sensing



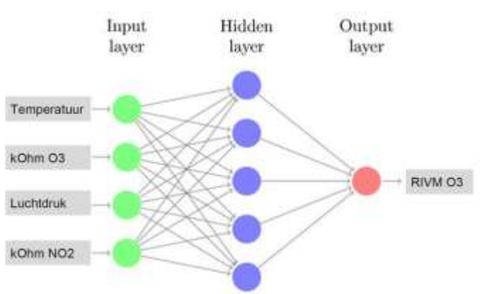


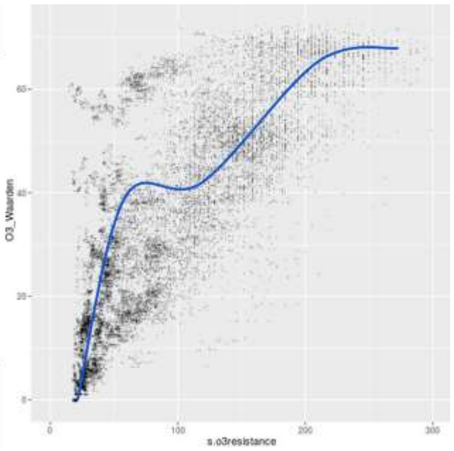
Interactive process with citizens and experts

during the pilot project 2016 – 2017, photos

Smart Emission project Nijmegen, Netherlands

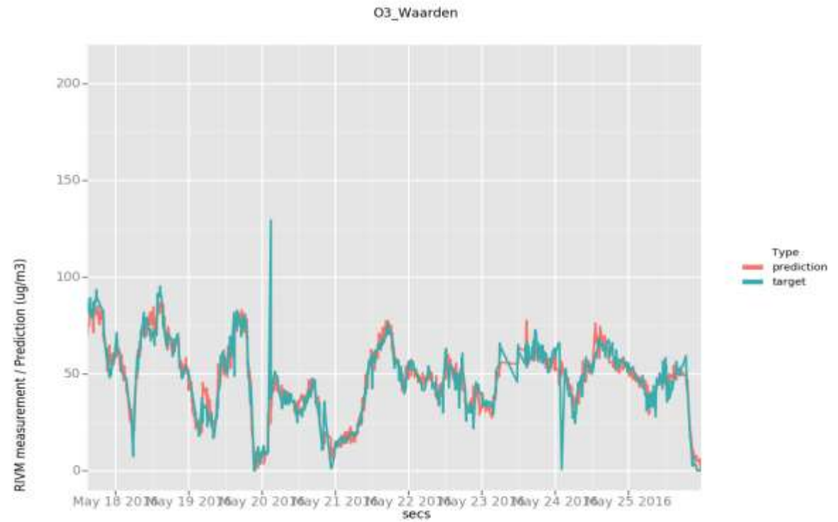
- Data analytics for **calibration of ozone** sensing (by data scientist: Pieter Marsman)
- Interpretation of case analyses with **students and citizens** in evening masterclasses

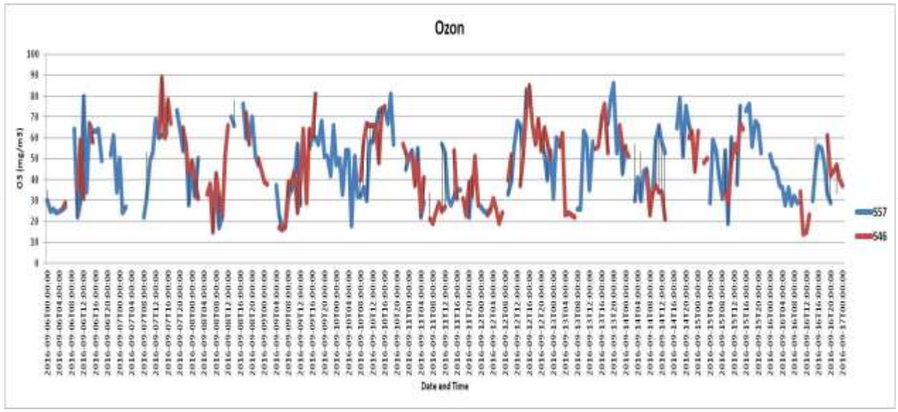


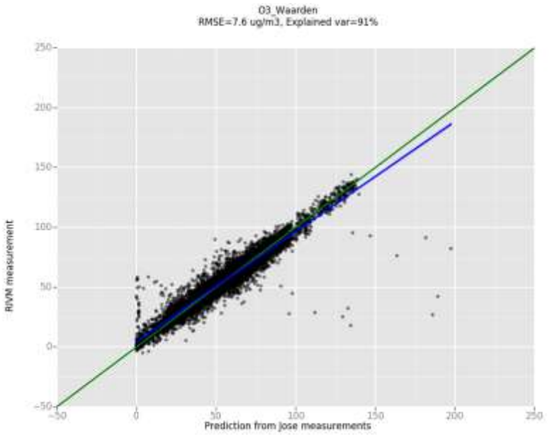


AI, neural network algorithm, training for 3 month: Finding sensor indicators that are relevant for calibrating ozone:

datetime	p.power.harvest.input.active	s.latitude
p.base.timer	p.power.mains.input.active	s.light.sensor.blue
p.co.heater.mode	p.power.nh3.sensor.on	s.light.sensor.bottom
p.co.heater.value	p.power.no2.heater.on	s.light.sensor.green
p.error.base.irq.service.stopped	p.power.no.battery	s.light.sensor.red
p.error.booting	p.power.o3.heater.on	s.light.sensor.top
p.error.configuration	p.power.pm.sensor.on	s.longitude
p.error.memory	p.power.usb.input.active	**s.no2resistance**
p.error.sensor	p.session.up.time	**s.o3resistance**
p.error.wifi.connection	p.total.up.time	s.rain.backside.left
p.no2.heater.mode	p.unit.serial.number	s.rain.backside.right
p.no2.heater.value	p.unknown.17	s.rain.frontside.left
p.power.aux_power.input.active	p.unknown.18	s.rain.frontside.right
p.power.charged	p.unknown.19	s.rgb.color
p.power.charging	s.accelero.x	s.satinfo.dilution
p.power.co2.sensor.on	s.accelero.y	s.satinfo.fix
p.power.co.heater.on	s.accelero.z	s.satinfo.num
p.power.energy.harvesting.standby	**s.barometer**	s.second.of.day
p.power.error	s.co2	**s.temperature.ambient**
p.power.gauge.ok	**s.coresistance**	s.temperature.unit
p.power.h2s.sensor.on	**s.humidity**	





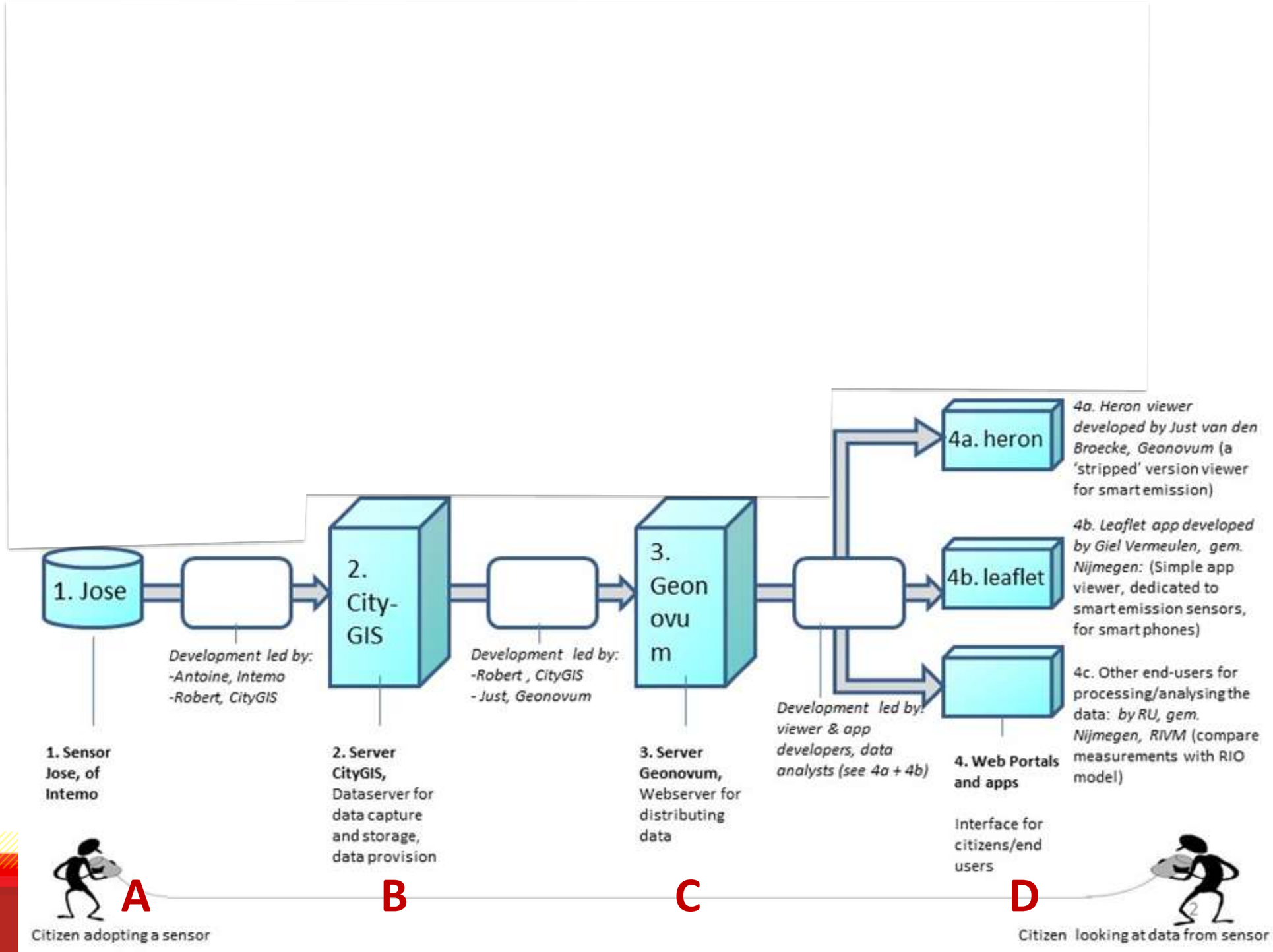


Radboud Universiteit

Pioneering in organizing: who does what in the data chain?

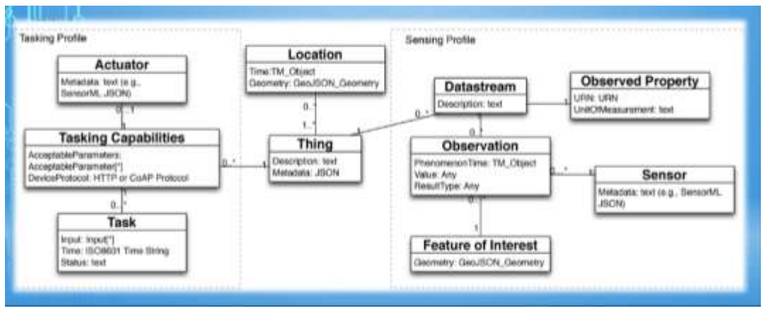
Work sketches, communicating outline of data chain

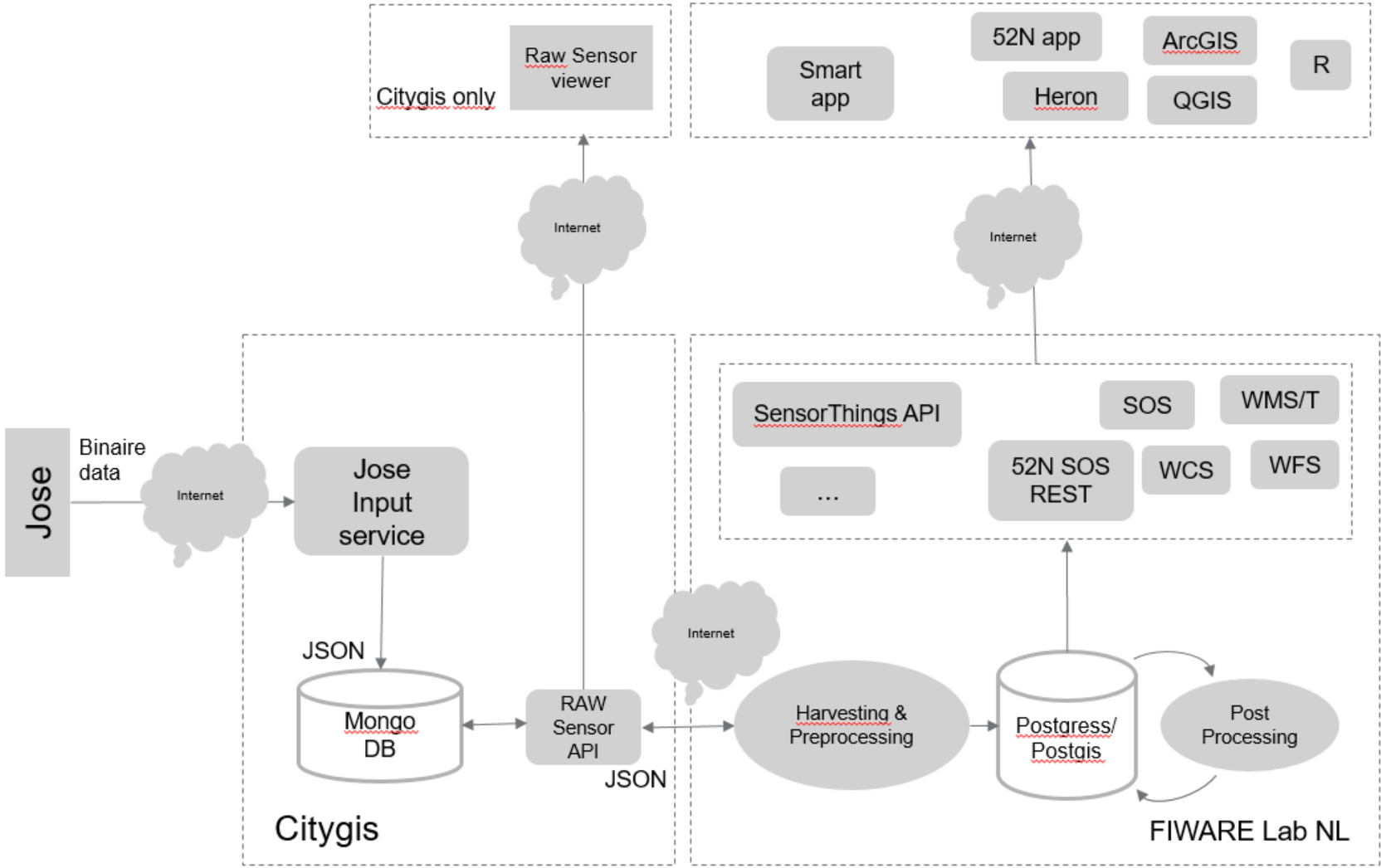
A: citizen scientists, end users
B: dedicated sensor hardware and software
C: Geonovum; government platform
D: Publishing, disseminating the sensor data



Technical design of sensor data infrastructure

SensorThings API, sensor observations:





Technical data infrastructure design by Robert Kieboom, Just van den Broecke, Paul Geurts, Michel Grothe, CityGIS and Geonovum

Thoughts of future improvements of a distributed architecture, multiple parties & roles Example

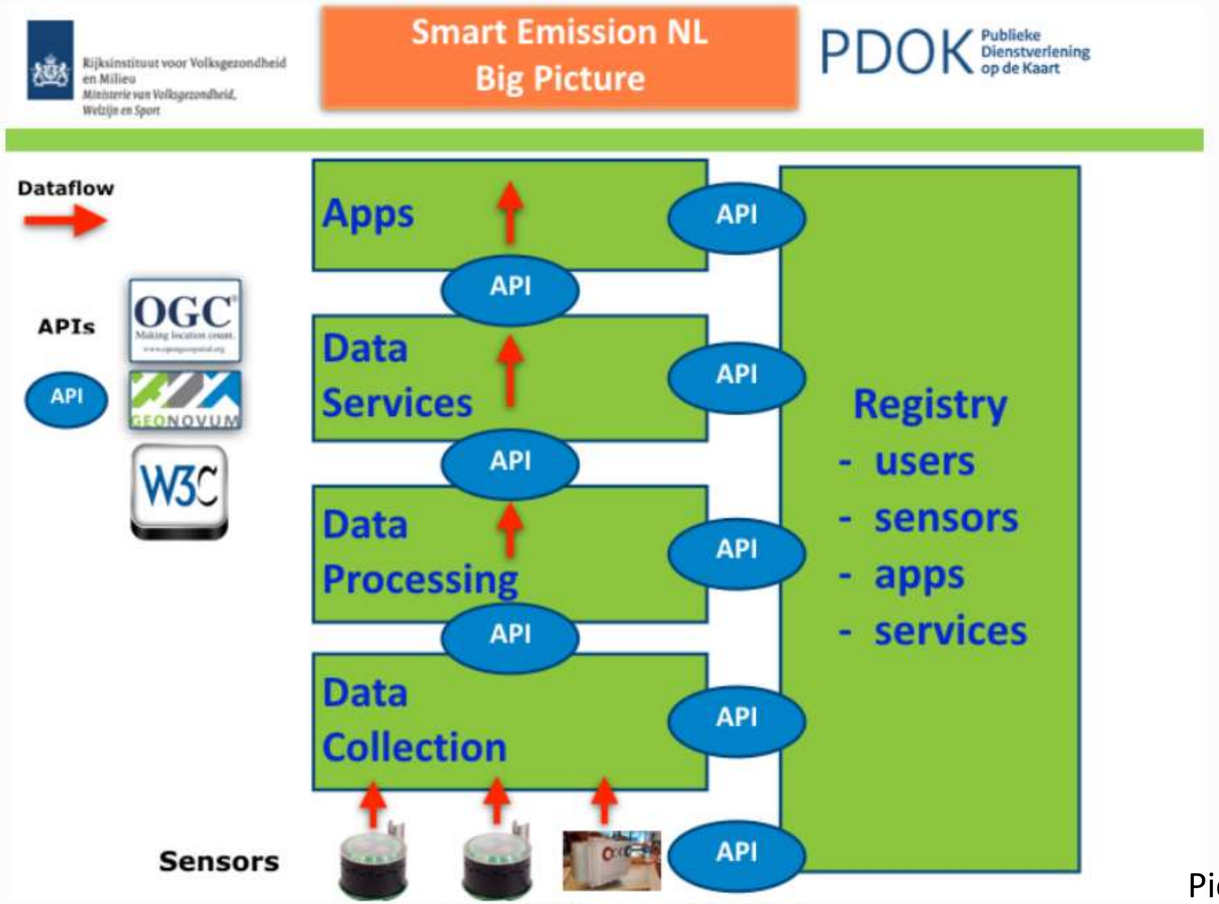


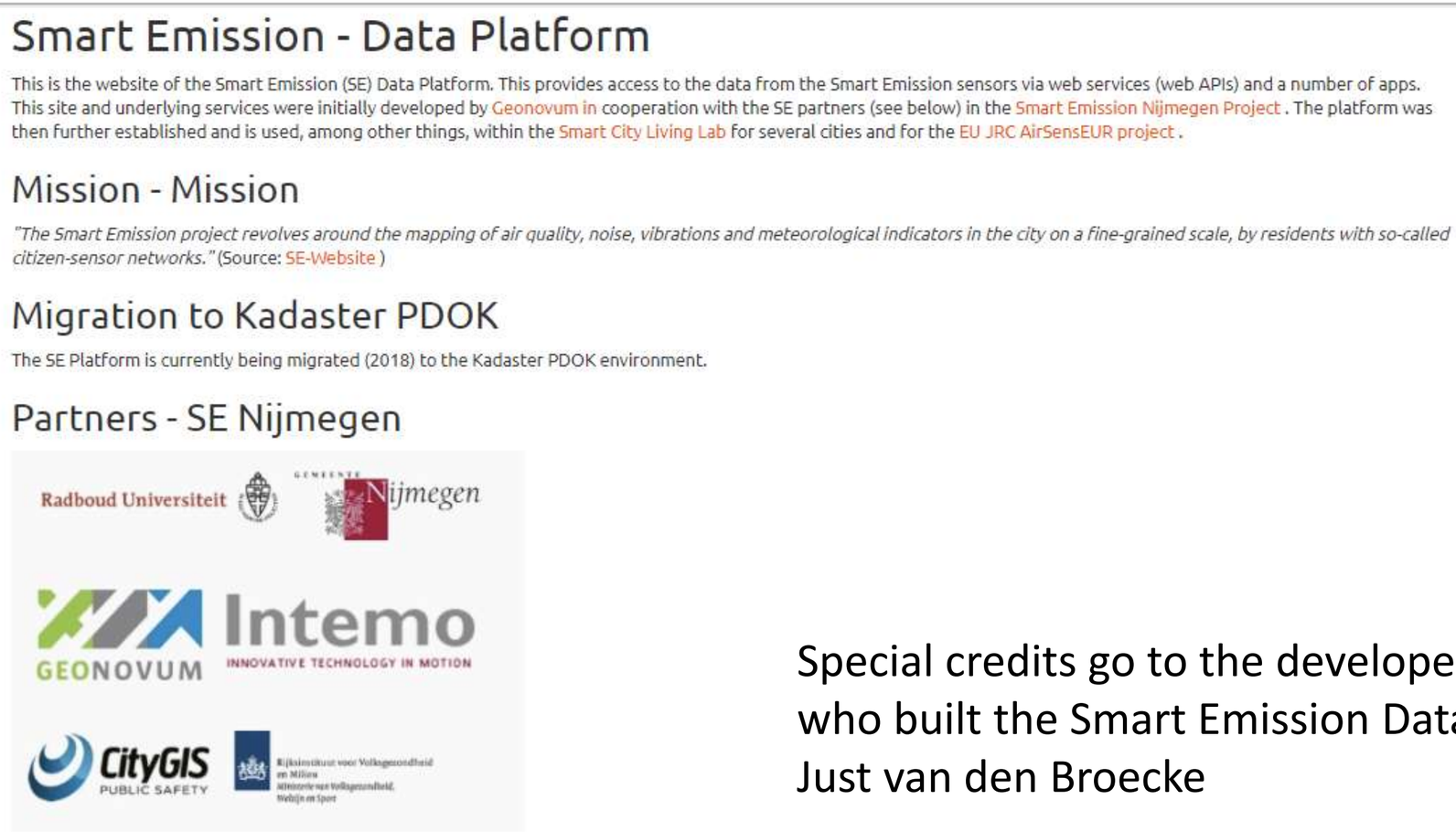
Figure 1 - Global Component Architecture

Picture: J.van den Broecke

https://smartplatform.readthedocs.io/en/latest/evolution.html, architecture discussion

Special credits: Just van den Broecke

Resulting Spatial Data Infrastructure for Sensor Data: illustration of the central data platform



Special credits go to the developer &programmer who built the Smart Emission Data Platform:
Just van den Broecke

Special credits go to the developer &programmer:
Just van den Broecke

Data

Data from the SE Platform can be viewed via the Viewers or retrieved via so-called "APIs". Please note the Disclaimer with the license conditions (link above)! Errors or irregularities in the data can be reported at github.com/smartemission/smartemission/issues .

By APIs

All APIs are based on OGC Standards. There are multiple APIs, dependent on goals (image, data, bulk-download) and also historically from research.

Name	Description	API Link	Documentation
SOS API	OGC SOS (XML) API for all (historical) values (52North)	SOS Capabilities	Docs
SOS REST API	idem as REST API for all (historical) values	REST Link	API Docs
OGC SensorThings API	SensorThings REST API (STA) by Geodan GOST Server	REST Link	OGC Standard, Wikipedia
WMS API	OGC WMS including WMS-Dimensions for Time	WMS Capabilities	OGC Standard
WFS API	OGC WFS e.g. for Download Timeseries	WFS Capabilities	OGC Standard
(**SOSEmu REST API***	SE JSON / HTML REST API only for last values	REST Link)	

* NB the SOSEmu REST API is temporary and will be phased out.

See also the Cookbook in the SE Documentation for using these APIs in clients.

Smart Emission (SE) Platf

data.smartemission.nl/viewers

Apps For quick access, place your bookmarks here on the bookmarks bar. Import bookmarks now...

This page has been translated. Options

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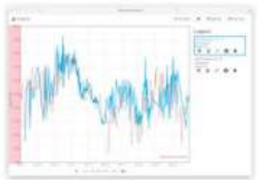
SE Platform | Home | Documentation | Viewers | Data | Left | Disclaimer | Contact

Apps and Viewers

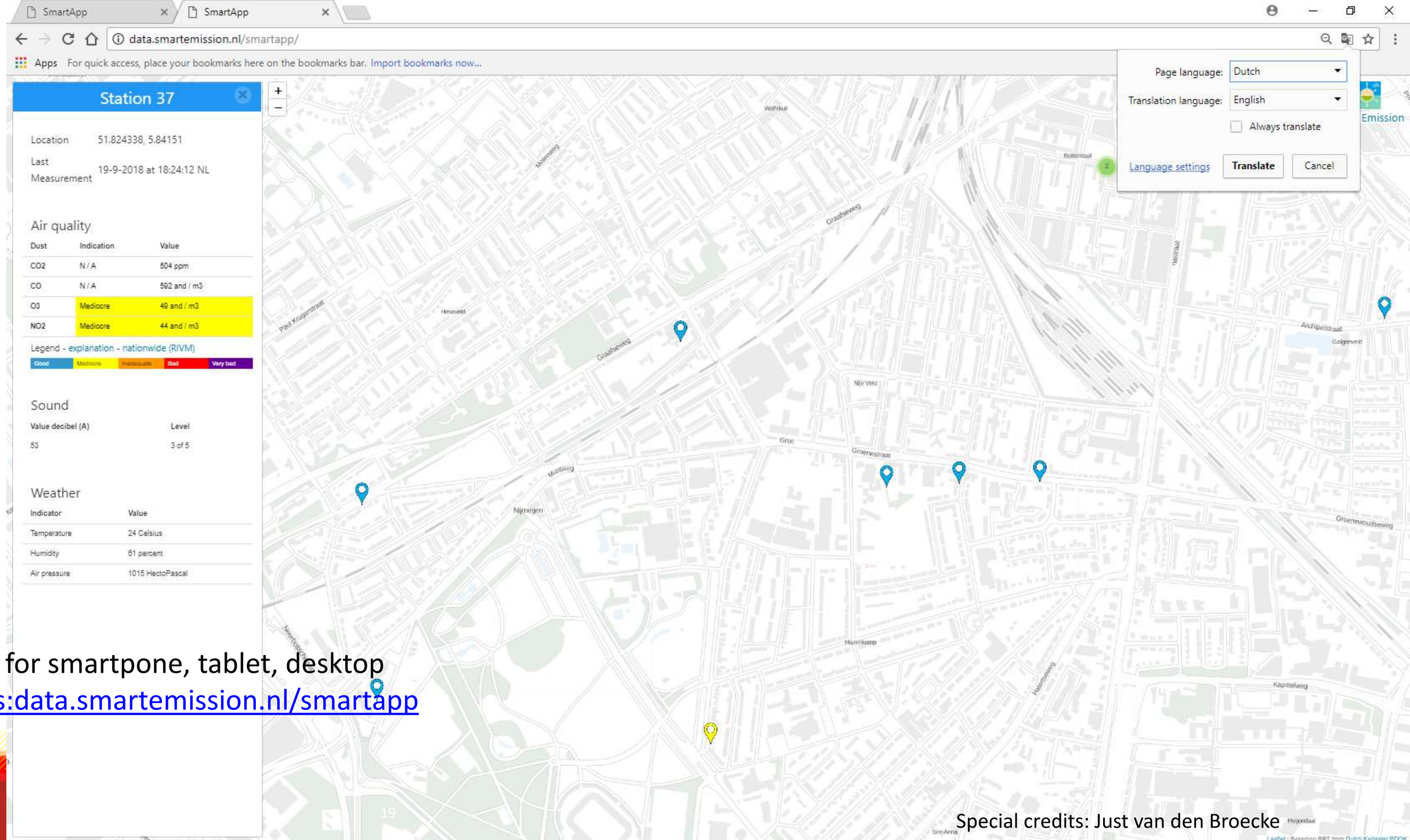
Thanks in particular to usage standards (see APIs), several apps are connected to the platform. Please note the Disclaimer with the license conditions (link above)!

Apps - Smart Emission

Apps developed within SE project

Viewer	Description
 SmartApp	last values, for Mobile / Tablet. Uses SOSEmu REST API.
 Heron Viewer	GISViewer for Desktop, uses WMS (Time) and WFS (Download), last values and history (WMS, via time slider)
 Waalkade Nijmegen	Project for Nijmegen Green Capital
 SOS Viewer (52North)	Aggregate hourly values, Timeseries, Charts, Download History. Uses SOS REST API.
	For raw / uncalibrated sensor data directly from sensors (CityGIS)

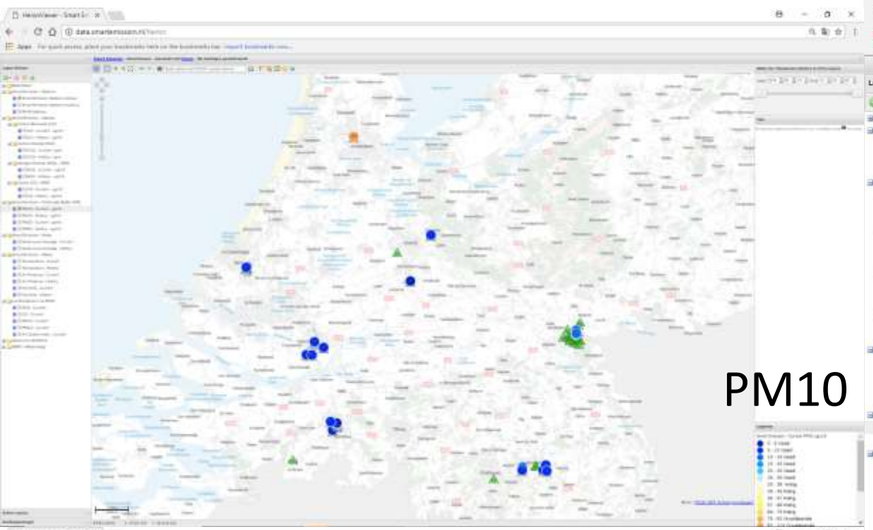
Special credits: Just van den Broecke

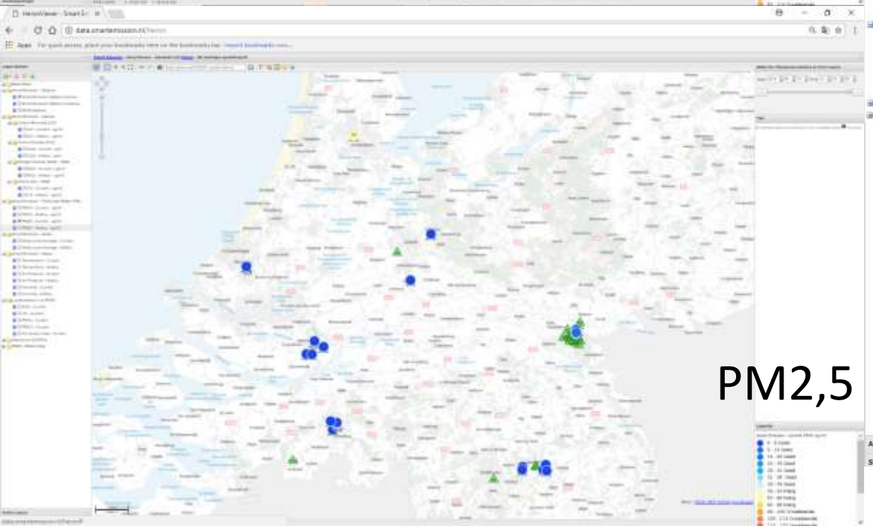


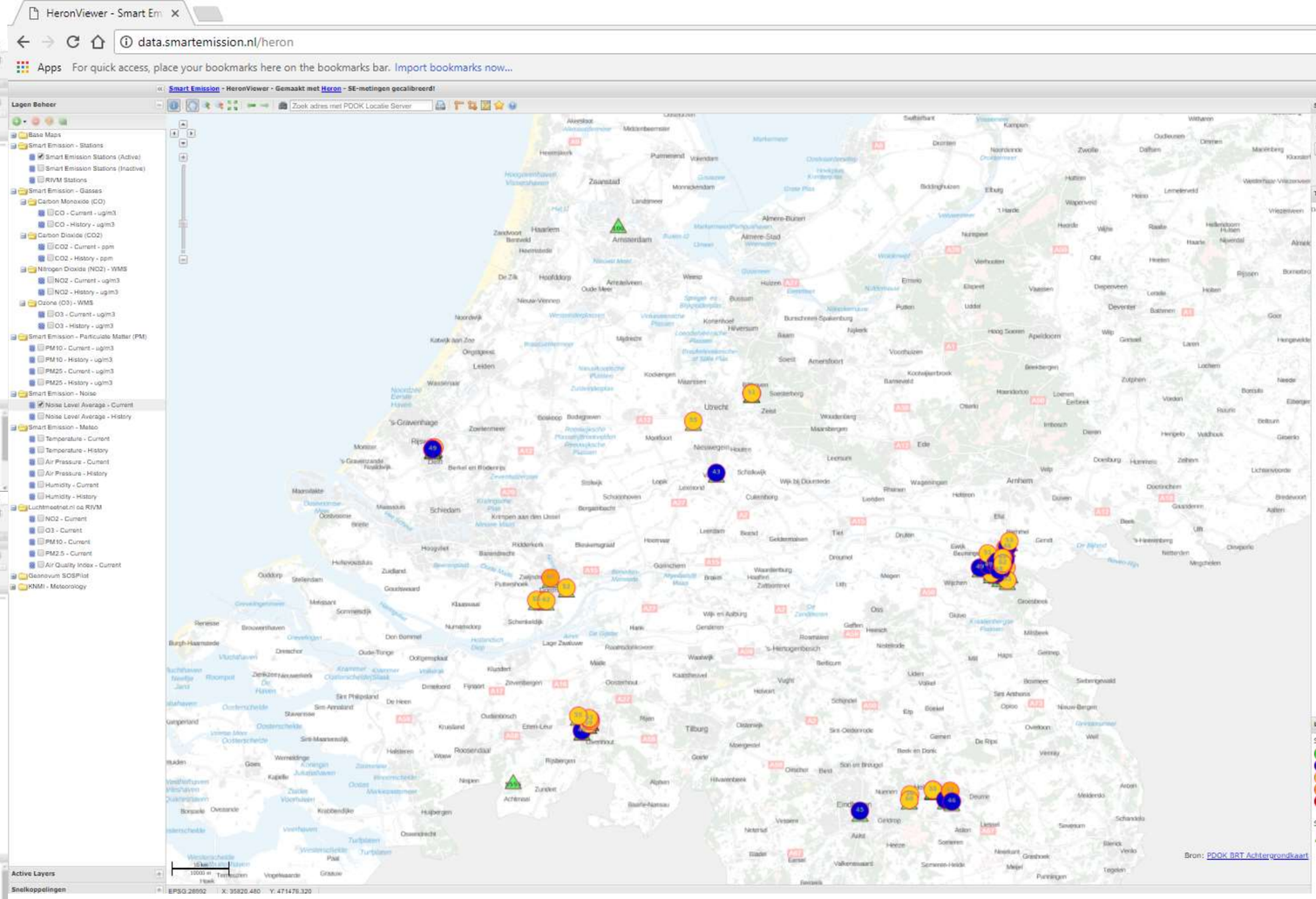
Live, for smartpone, tablet, desktop

https:data.smartemission.nl/smartapp

Special credits: Just van den Broecke







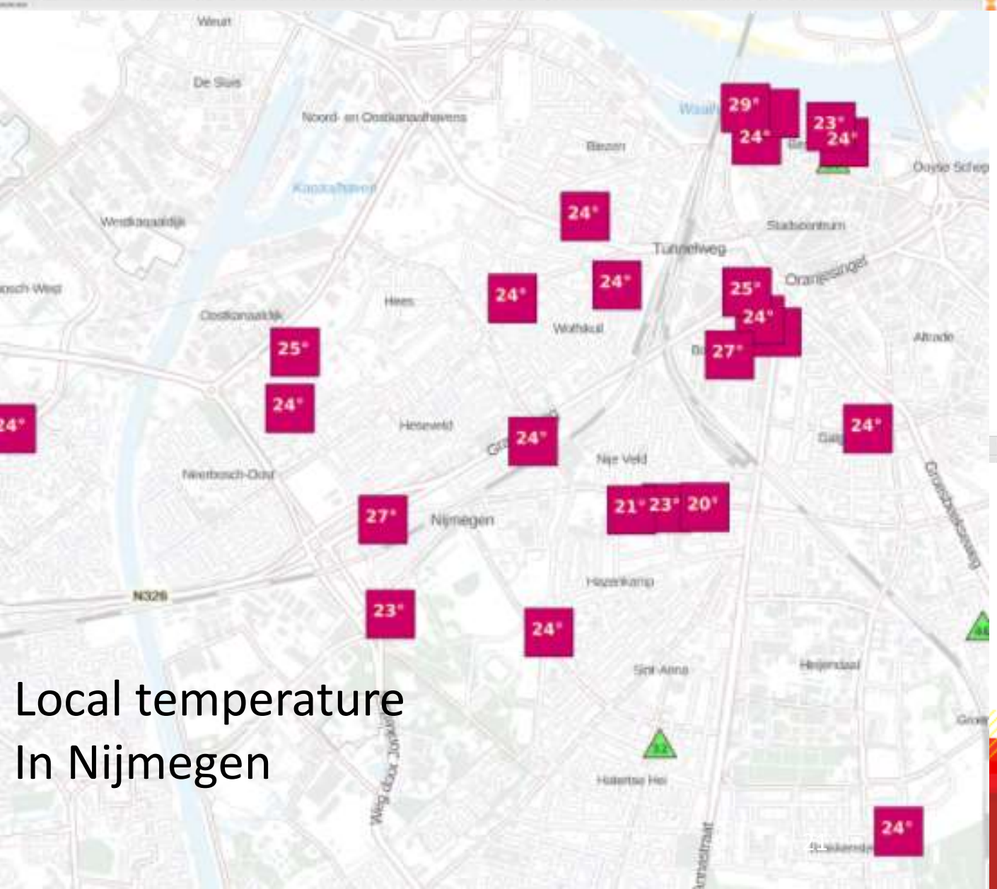
Noise

Live:
https:data.smartemission.nl/heron

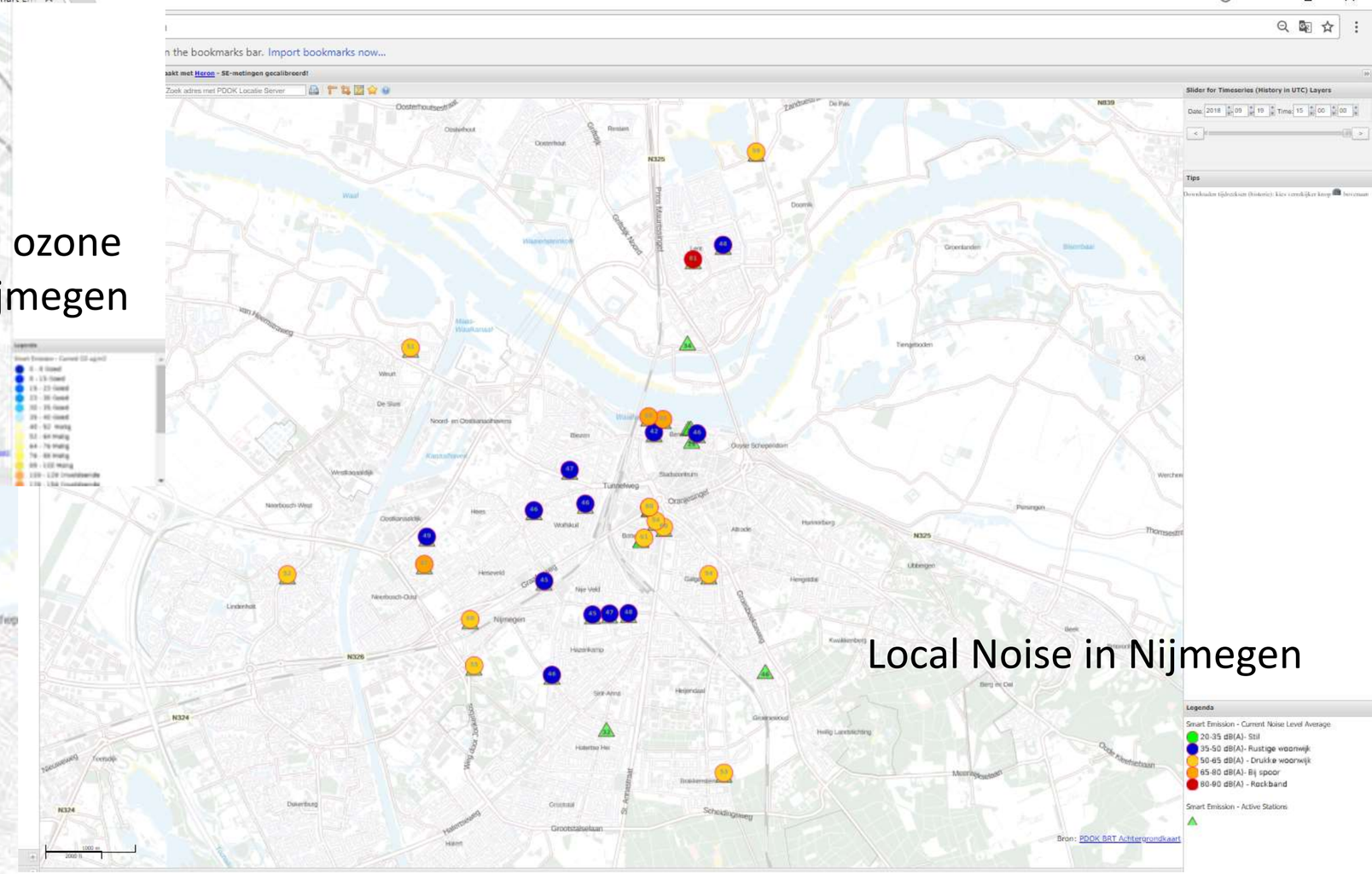
Experimental National Spatial Data Infrastructure for sensor data, used by multiple projects: 1. Smart Emission, 2. National Smart City Living Lab, 3. Nijmegen Green Capital Waalkade monitoring

Special credits: Just van den Broecke

Local ozone
In Nijmegen



Local temperature
In Nijmegen

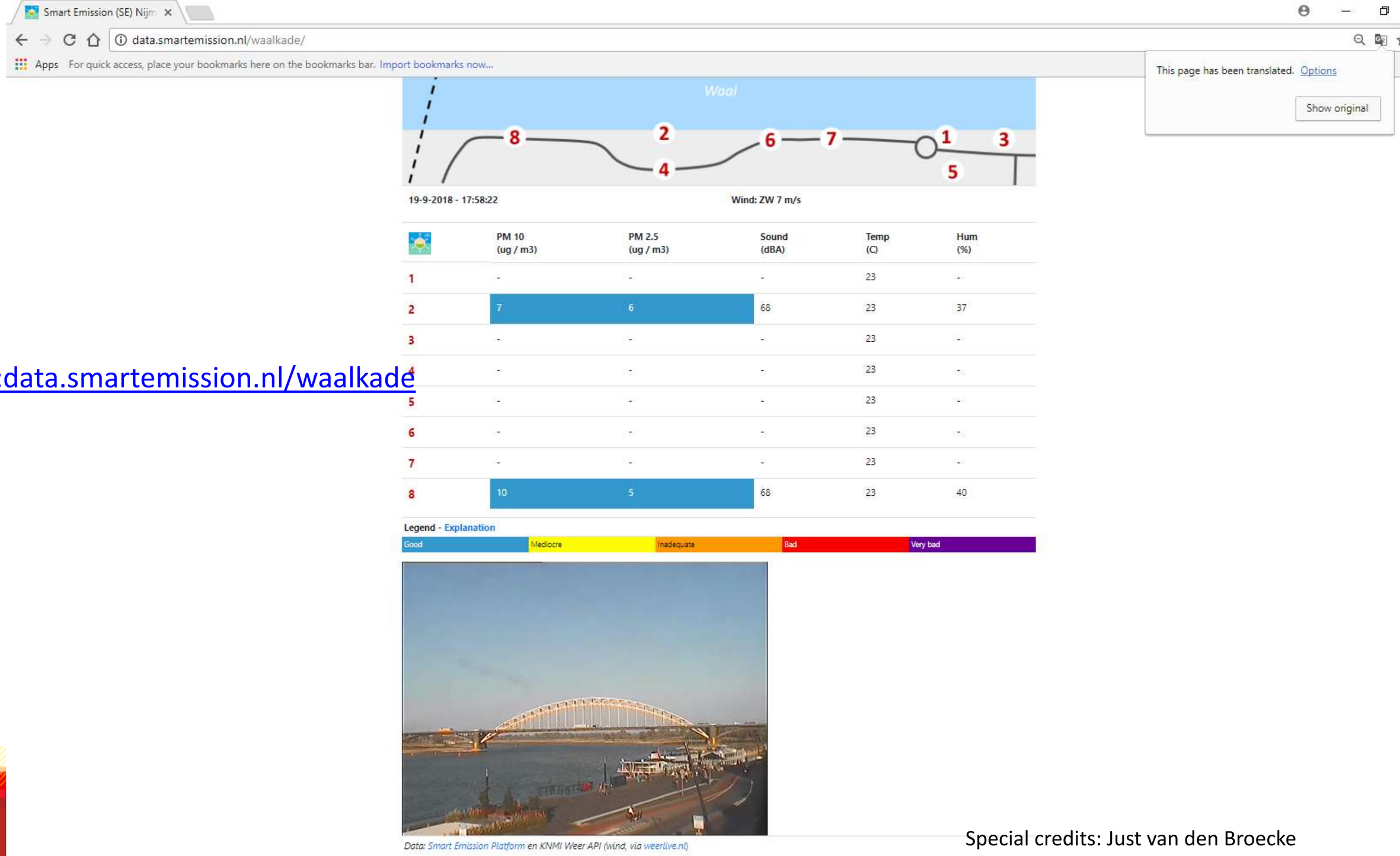


Local Noise in Nijmegen

Live GIS viewer for desktop: [current data]
One legend for multiple sensed environmental indicators
https:data.smartemission.nl/heron

Special credits: Just van den Broecke

Live:
https:data.smartemission.nl/waalkade

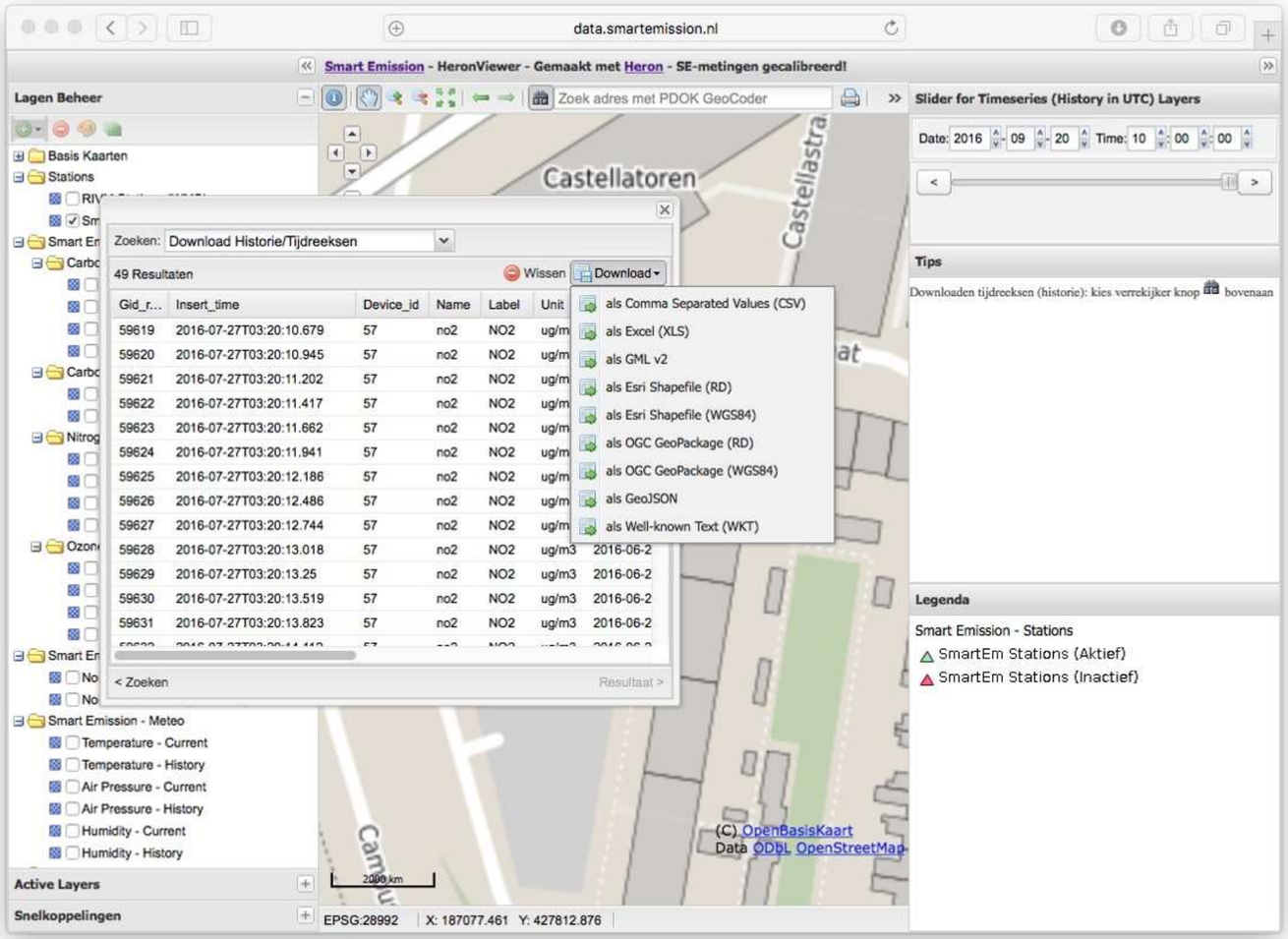


Special credits: Just van den Broecke

Sensor Data Download service

Timeseries download option used:

- CSV and **Excel format useful for citizen** scientists
- **GIS format (ArcGIS) useful for students** with Geo background
- GML and GeoJSON **useful for web programmers**



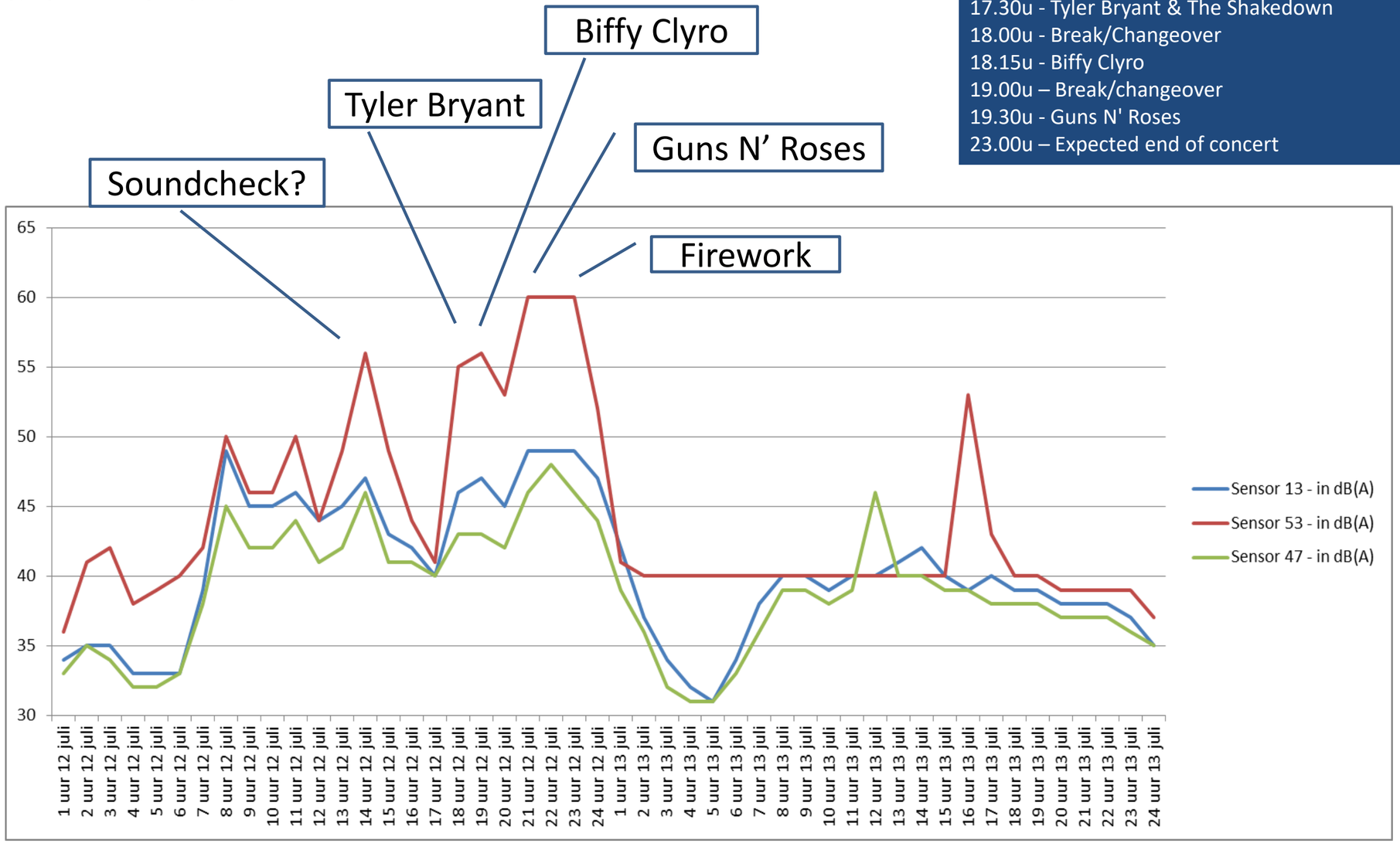
Citizen request: aggregate the timeseries based on requests to the database, when you ask for downloading:
Create Timeseries with scalable range/smallest unit (day/minute-averages), (week/hour averages)

Use case by Nijmegen citizens: Goffert Park pop concert Guns N'Roses, 12 July 2017

Graphic of analysis noise sensors, made by citizen scientists, using sensor data download and Excel

P. Biemans and E. Biemans

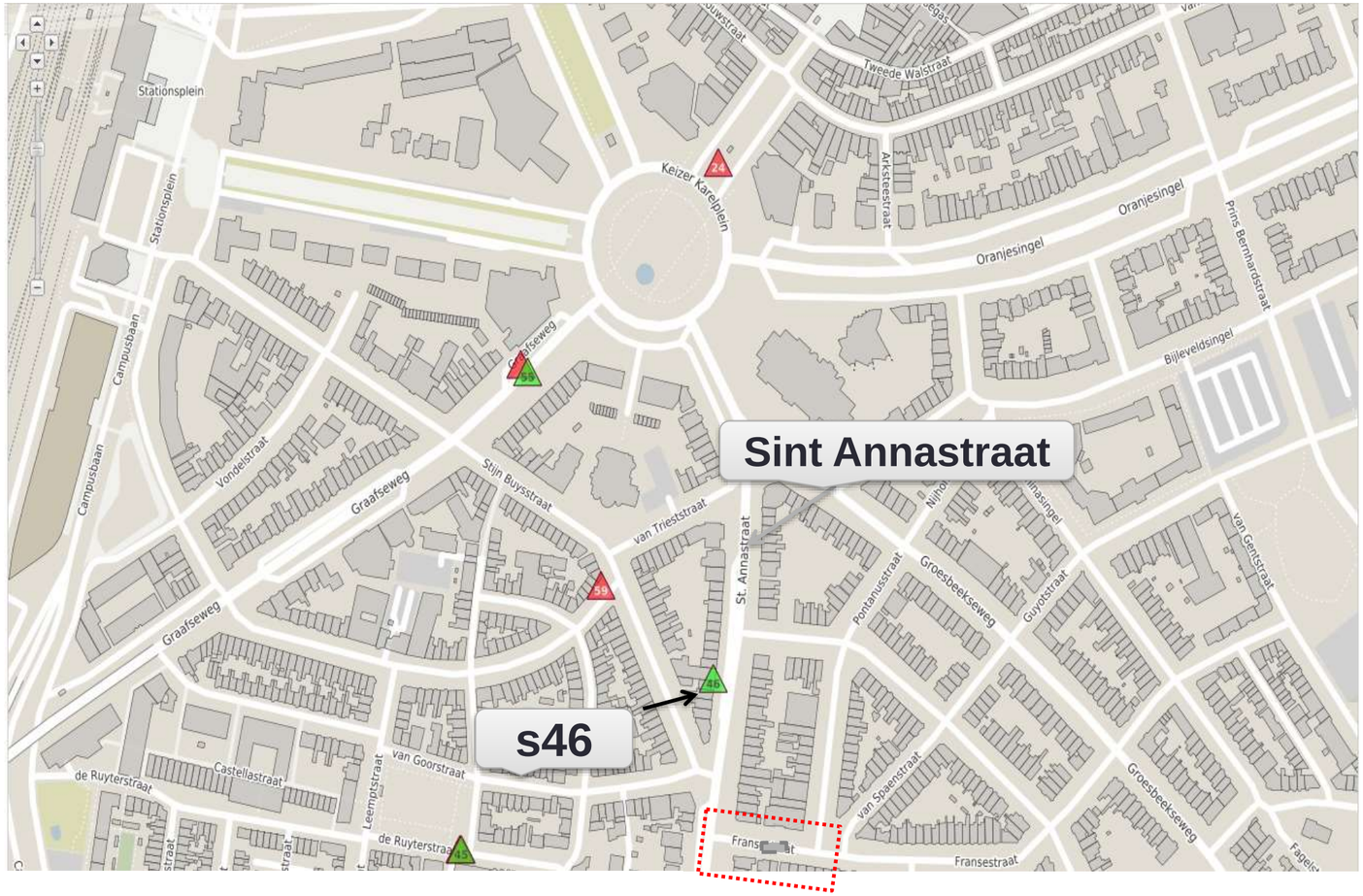
15.30u - Terrain opens
17.30u - Tyler Bryant & The Shakedown
18.00u - Break/Changeover
18.15u - Biffy Clyro
19.00u – Break/changeover
19.30u - Guns N' Roses
23.00u – Expected end of concert



Use Case: Signaling episodes of increased noise levels

Regulations, a permit for live music on a street-podium has been issued, with licence to operate: “until 18:00 in the evening.”

The historically stored hour averages show that the music level was elevated unil 22:00.



S46	
time (22-7-2016)	noise (dBA)
0:00:00	38
1:00:00	41
2:00:00	40
3:00:00	38
4:00:00	40
5:00:00	40
6:00:00	35
7:00:00	39
8:00:00	36
9:00:00	39
10:00:00	39
11:00:00	56
12:00:00	60
13:00:00	60
14:00:00	
15:00:00	60
16:00:00	70
17:00:00	60
18:00:00	64
19:00:00	58
20:00:00	55
21:00:00	56
22:00:00	43
23:00:00	40

Student assistants exploring various use cases in the data. (Zoi Katsamani, Freek Thuis)

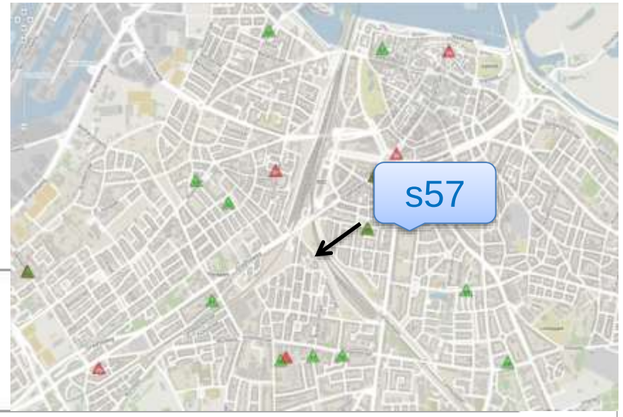
Use case: Pattern in daily ozone forming during car-free

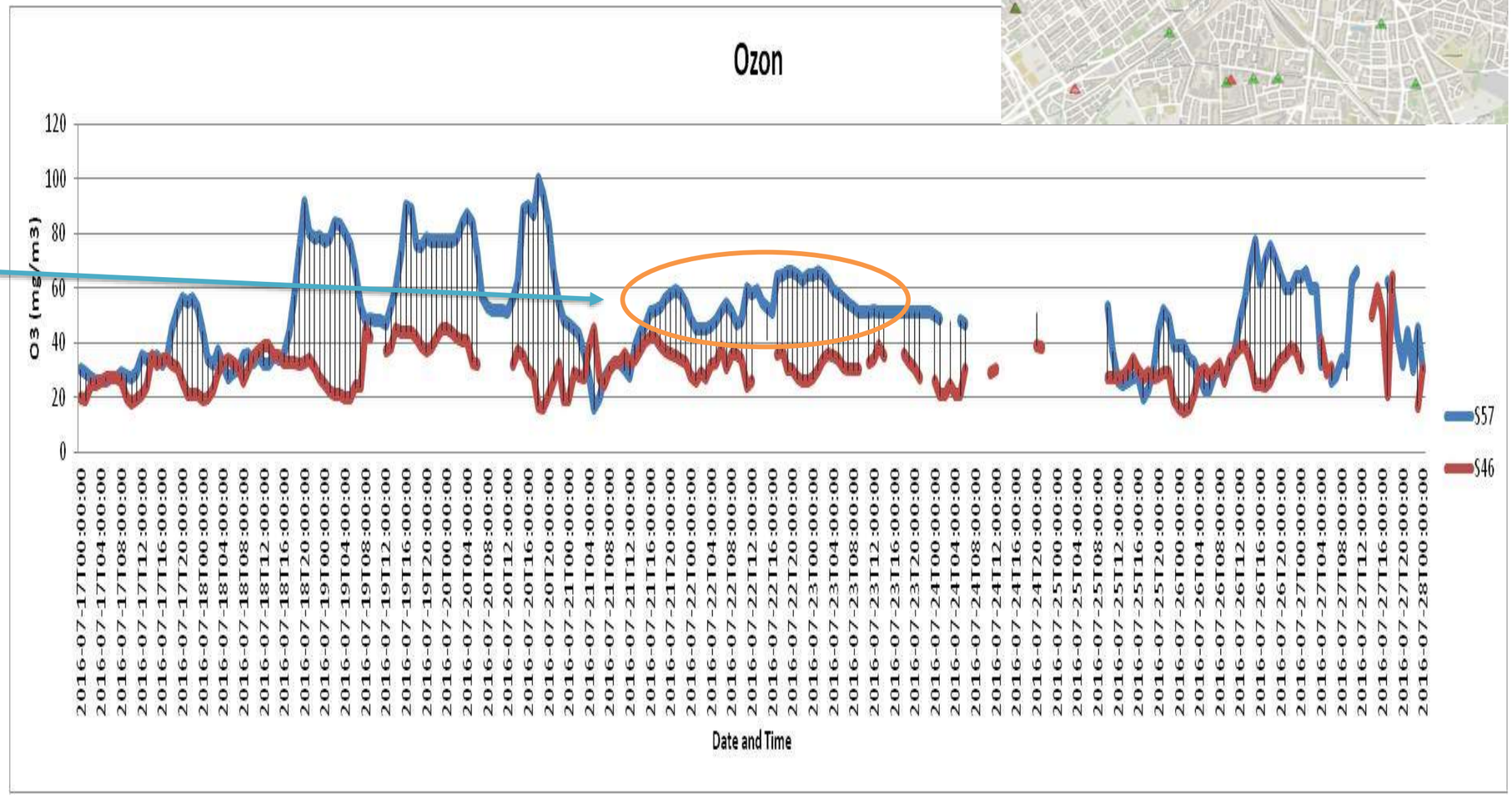
4-day walking festival “Nijmeegse Vierdaagse”

Groenestraat (sensor 57), experiences less traffic during these days,

and sensor 57 shows indeed no high ozone peak measured during Vierdaagse,

While on regular days, ozone peaks here (around 80 mg/m3)





Student assistants exploring various use cases in the data. (Zoi Katsamani, Freek Thuis)

Follow-up with the Sensor Data Infrastructure

After closure of the Smart Emission project,
no budget left for maintaining the data platform.

Typical valorization gap: *investment subsidy for small pilot, no attention for follow-up.*
Split incentives for scientists, researchers on one hand, and 'valorization development' for scaling towards societal applications for market parties and (government) customers on the other hand.

Follow up with the Sensor Data Infrastructure

After closure of the Smart Emission project,
no budget left for maintaining the data platform.

We made a Leaflet:
Effort to ask public governments, who funded the pilot, to adopt the platform.
(here one page of the 2-pager, translated to English)

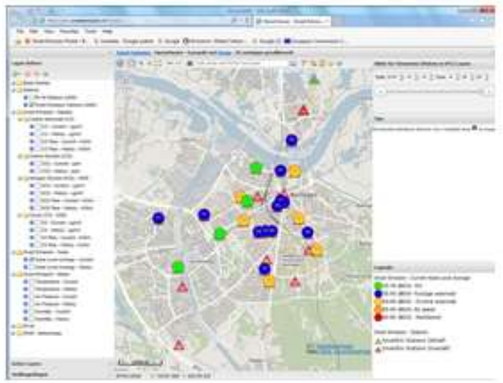
Typical valorization gap: *investment subsidy for small pilot, no attention for follow-up.*
Split incentives for scientists, researchers on one hand, and 'valorization development' for scaling towards societal applications for market parties and (government) customers on the other hand.

Smart Emission

Open Sensor Data Infrastructure

Open Sensor Data Infrastructure

The Smart Emission Data Platform as an example of a Private-Public Shared Data Platform
The data platform is made up of a commercial part and a government department, in which the parties have cooperated exceptionally well. Where the commercial part is mainly designed to guarantee the continuity of both the sensors and the viewer, the government and science are mainly interested in the platform for analysis and research purposes, which also requires developments on the platform. It is desirable that the government part can provide continuity (just like the PDOK services) as well as provide an analysis and development platform for further research and further development of services, for more sensor networks and improvement of the sensor-data production chain (also data- optimization 'at the source').



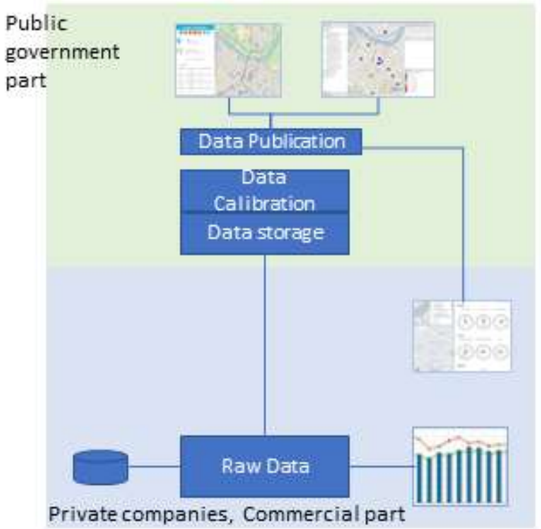
Info about the Smart Emission Data Platform

What is it: An online platform where in near-real-time raw data from a sensor network is retrieved, processed, stored, aggregated, and made available via various APIs such as Open Data, and visualized in various dashboards and viewers. The platform was built with the cooperation of consortium partners Geonovum and CityGIS.

What does it do: The platform retrieves online sensor data, provides historical data storage, and publishes the data as processed, Open Data. Examples of processing layers: Using an Artificial Intelligence (neural network) algorithm, an optimal calibration correction factor is applied to individual sensor parameters, so that the NO2 value is corrected for, for example, temperature and air humidity. A sound value in dB (A) is calculated from individual frequency bands. Historical values are calculated and a minimum, maximum and hourly average is saved. There are wishes for more and other aggregations on the data flow, for example minute averages for sound. All processing layers are documented (open source).

Who use it: - Residents united in "citizensensor workgroup Nijmegen" - municipality Nijmegen - Radboud University, TNO - Hexagon and ImageM, JEDecaux, Luchtradar Utrecht

What do these parties want: To improve the sensor network that hangs there, and to experiment with citizens (citizen-scientists) and professionals in air and sound Studies in Data Science and Citizen Science, with applications for smart cities, environment and innovative governance models. More (citizen) initiatives help to establish a similar sensor network, also with other sensors.



Actor Analysis

By Jene van der Heide, Dutch Kadaster

Citizens interest

- I want to know if I'm being sensed, by whom and what happens with the data
- I want to know about the (development of) air quality, sound levels, traffic density, ... in my surroundings
- I want to move, how about the air quality, sound levels and congestion in my (possible) new neigbourhood?

Governments interest

- Sensors help building a better, safer, healthier, accessible and sustainable city
- We make use of present sensors and prevent using doube investments and measurements
- We are open to our users to show what is being sensed where and by whom

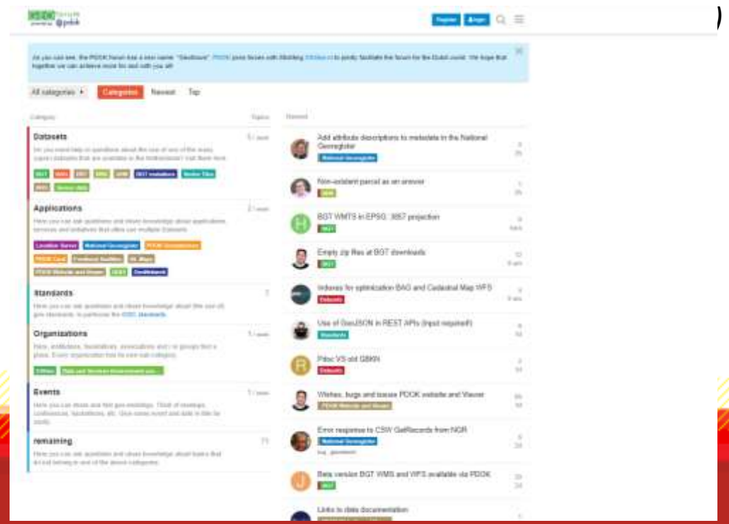
Companies interest

- I want to be transparant about the location of my sensors and what they do
- I want to make use of sensor data but I don't want to invest in sensors myself
- I want to use sensor data to implement new services and products

Sensor Data Platform
adopted by Kadaster for filling gap to more research

More information on this sensor data infrastructure:
data.smartemission.nl

Open platform design explained on **Geoforum** (PDOK Forum) for the adoption by the Dutch Kadaster:
https://forum.pdok.nl/t/even-voorstellen-smart-emission/1489
Expert and editor: Just van den Broecke, for Dutch Kadaster and Intemo.



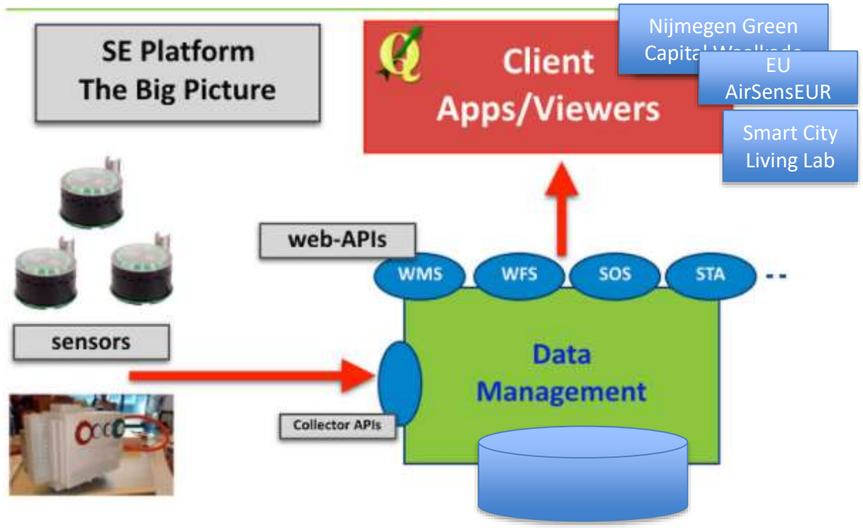
GEOforum powered by pdok

Introducing: Smart Emission

Datasets | Sensor data | sensors , smartemission

Just_OSGeo OSGeo — 26 jun.

"Sensor data" is perhaps still a strange duck here under Datasets. Within this main category, it is now mainly about "geo-data". Sensor data, for example measurements of air quality, noise and weather (meteo-) data, as referred to here, is in fact also geodata: measurements also have coordinates. But in addition, sensor data also has an extra dimension (attribute): ***Time*** . That is why sensor data is often more formally called ***"spatiotemporal data"*** .



Smart Emission 2 is a project in which citizens have placed sensors that continually measure air quality (fine dust, gases), noise (decibels) and weather (temperature, air pressure, air humidity). This data is collected in the Smart Emission Platform 3 and accessed there through OGC standards (WMS, WFS, SOS, SensorThings API) and Viewers 1 . The Smart Emission project started (2015) in the municipality of Nijmegen with partners Radboud Uni, Geonovum, Intemo, RIVM, CityGIS. The platform proved so powerful that other projects such as the Smart City Living Lab 1 (municipalities) and the EU AirSensEURconnected to this. In order to keep this platform consistent and scalable "in the air", and in view of the future INSPIRE obligations with regard to sensor data (INSPIRE is ultimately about the environment!), Housing in PDOK was a logical choice. Currently this migration is in full swing. In addition, the Platform will be rolled out as first PDOK application in "the Cloud", ie in a Docker-Kubernetes infrastructure.

Much, actually everything, around the platform is "Open":

- Open Source: via https://github.com/smartemission/ 4
- Open Docker Components: via Docker Hub: https://hub.docker.com/r/smartemission/ 2
- Open Data: via standards: http://data.smartemission.nl/data 1
- Open (Development) Processes: via issue tracker 1 and Project "Kanban Boards" 1 .
- Open Documentation: via ReadTheDocs

What we see happening now in the Netherlands

- **More citizen initiatives want to start measuring** air quality, noise. (but how?)
- National Institute for Public Health and Environment has launched a research agenda on Citizen Science, with a program "**Measuring together**"

What we see happening now in the EU

Multiple methods and technologies for air quality monitoring by citizens are emerging in Europe:

- amongst others the **Luftdaten method** for fine dust (PM10 and PM2,5) in Germany and spreading over Europe, and **NO2 monthly measurements by tubes** in London and Barcelona with schools
- NGO's, active citizens and researchers involved come together in various projects and associations: FabLabs (**Barcelona**, WAAG Society **Amsterdam**, Open Knowledge Lab **Stuttgart**, Mapping for Change **London**), WeMake the city in **Milan**, SmogAlert in **Poland** (6 December Katowice clean air day event during COP24), *Hackair*, *AirSenseur*, *ECSA* working group Citizen Science for Air Quality, INSPIRE…

Conclusion:

- Smart Emission project Nijmegen, Netherlands, is just one of many projects with citizens active in air quality monitoring

- Working together requires data that is standardized, interoperable, shared as open data, and understandable, easy to use
  - *suggestion: for undergraduate (bachelor) student level or high school level*

- National governments can create added value from this societally upcoming phenomenon:
  - Provide for a Public, Open Spatial Data **Infrastructure for Sensor Data flows** that can be used by multiple initiatives, under transparent and governed conditions. This requires some infrastructure costs.
  - A fine-grained, **in-situ, environmental monitoring network becomes much more low-cost, also for governments,** if professionals and citizen station data can be shared.

Discussion

- In the Netherlands, 21 September 2018: Discussion with all citizen initiatives on air quality monitoring at National Institute for Public Health and Environment (RIVM)

- Fine-grained air quality monitoring in cities: not only monthly and annual averages, but also peak episodes and regular, systemic dynamics in the daily practice of cities and its residents.
- Measure more, make less model assumptions

- *Message: Discussion on needs, (dis-) advantages and implications of the idea to establish a public spatial sensor data infrastructure, where small sensors (from citizens initiatives) can be included, for fine-grained measurement of environmental indicators (ozone, NO2, PM10, PM2,5, noise, temperature, etc.)*

Thank you!

A future-proof city is busy with its energy efficiency, transport systems, emissions, air quality, and ‘greening’ the city for mitigating climate change, preventing heat stress and safeguarding health.

Governments: Act as orchestra, citizens make the music

Greening the city and its advantages (Master thesis AnoukRuijters)