



Make it work together
INSPIRE 2018
Antwerp

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

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

Content of presentation

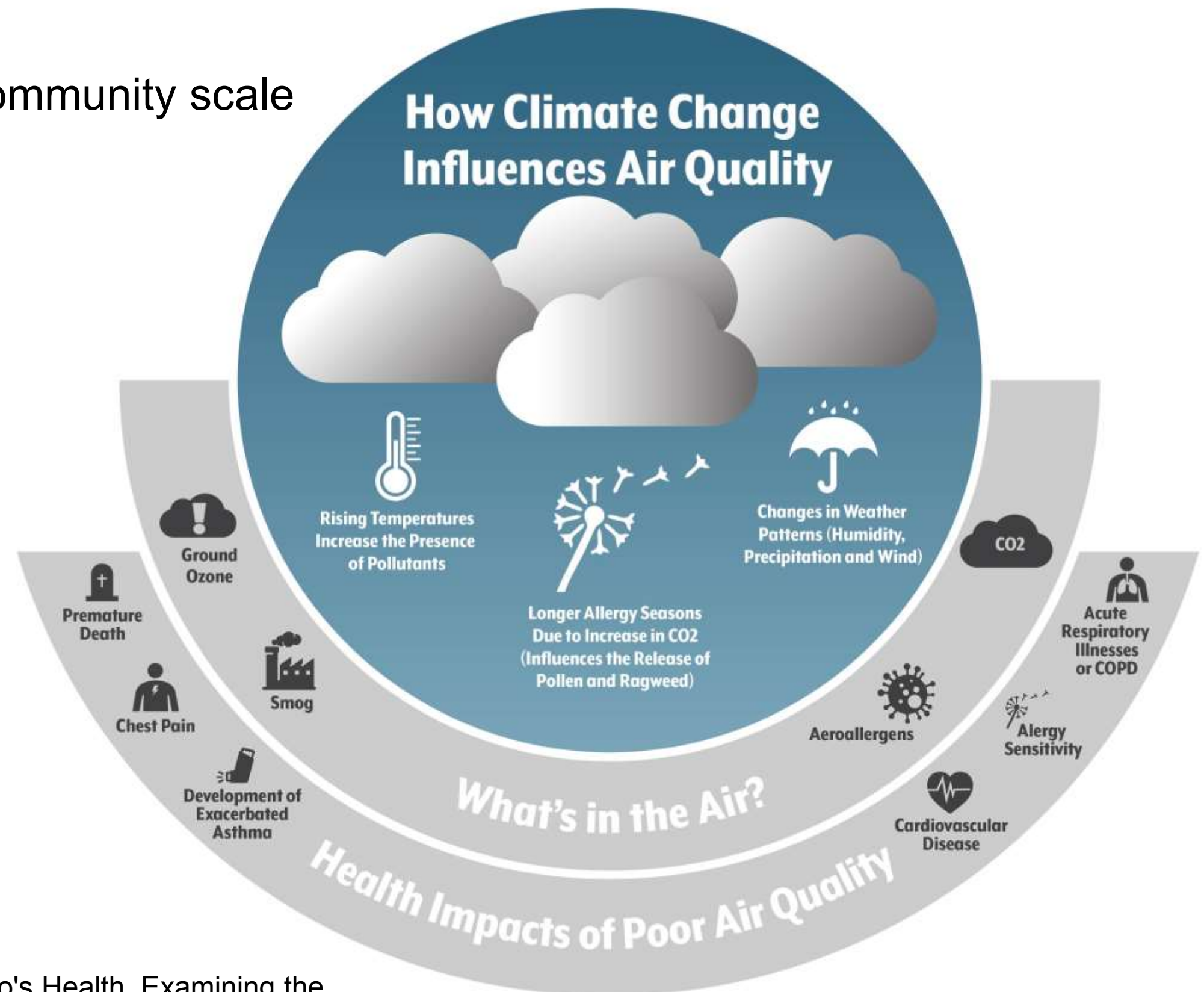
- **Introduction:** Relevance
- A Dutch pilot as case study, **Smart Emission:** Development of data chain and sensor data processing infrastructure, with citizens as end-users, in a city (Nijmegen)
 - Developed, description of parts of the **sensor data infrastructure** as built for Smart Emission
 - 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, PM_{2,5}, noise, temperature, etc.)*

Relevance: Aggravated 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

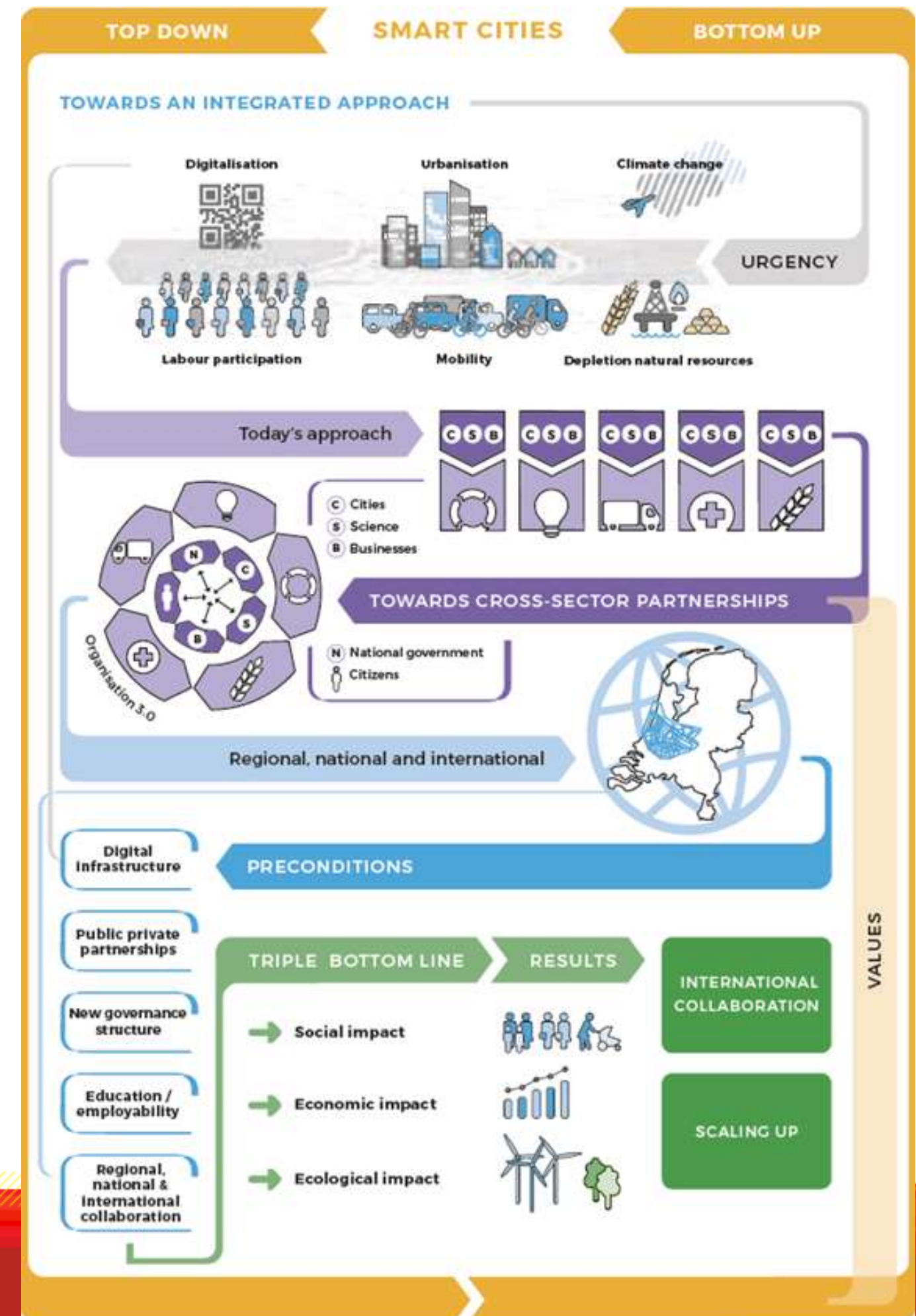
Smart cities, a national strategy document

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

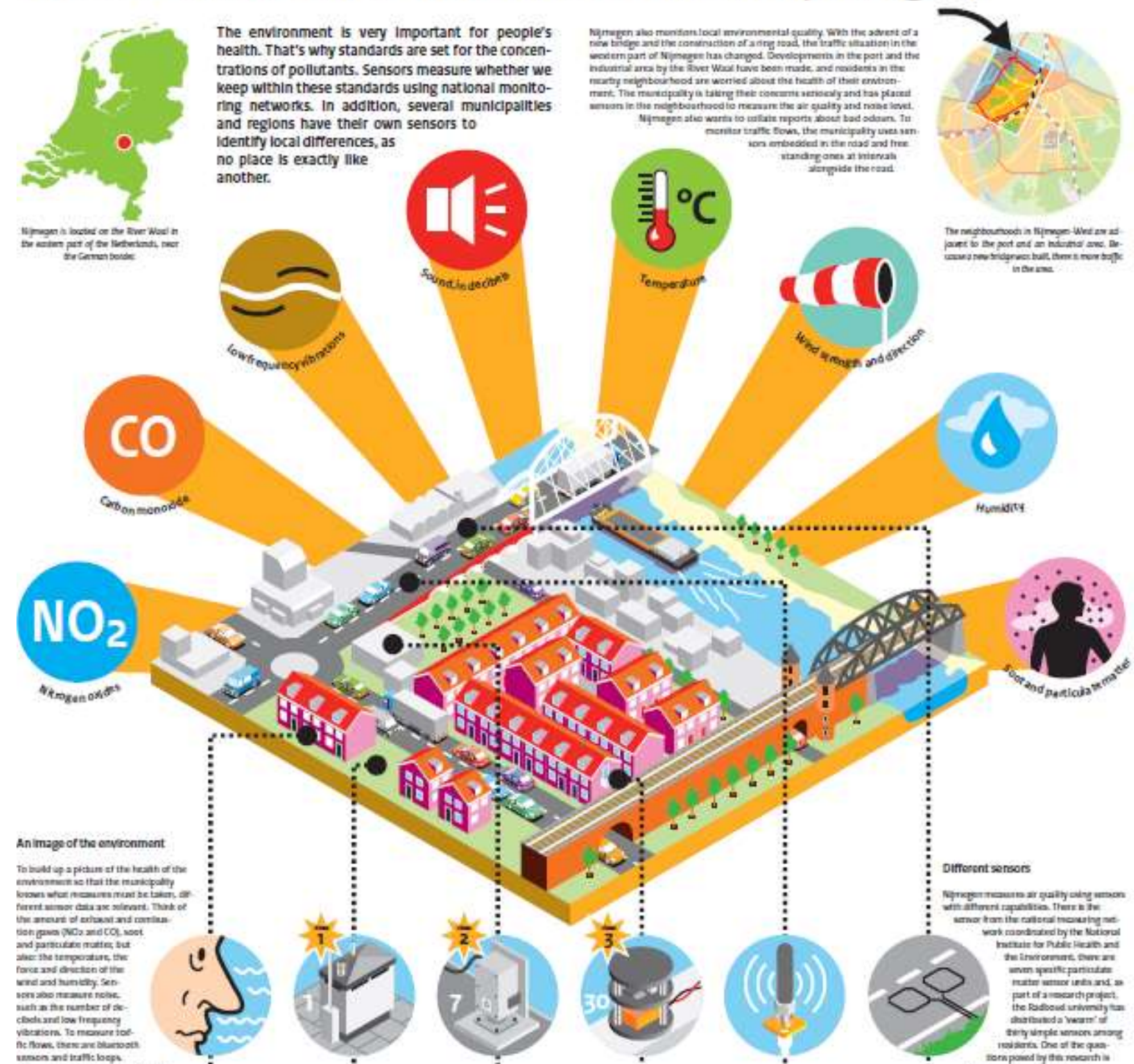
2015 -2017, city of Nijmegen

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?

Case: Environmental health in Nijmegen



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



Core concept Smart Emission project:

The smart residents

well-informed residents create solutions themselves



By taking part in the research being conducted by Radboud University, residents in the West can take measurements in their own neighbourhood over the next five years and think of ways of improving the air quality.



Researchers approach the residents and ask if they want to measure the air quality.



The residents then receive a simple sensor which they can put up near their home.



The university processes the measuring data from the sensors and then converts it into a visual image.



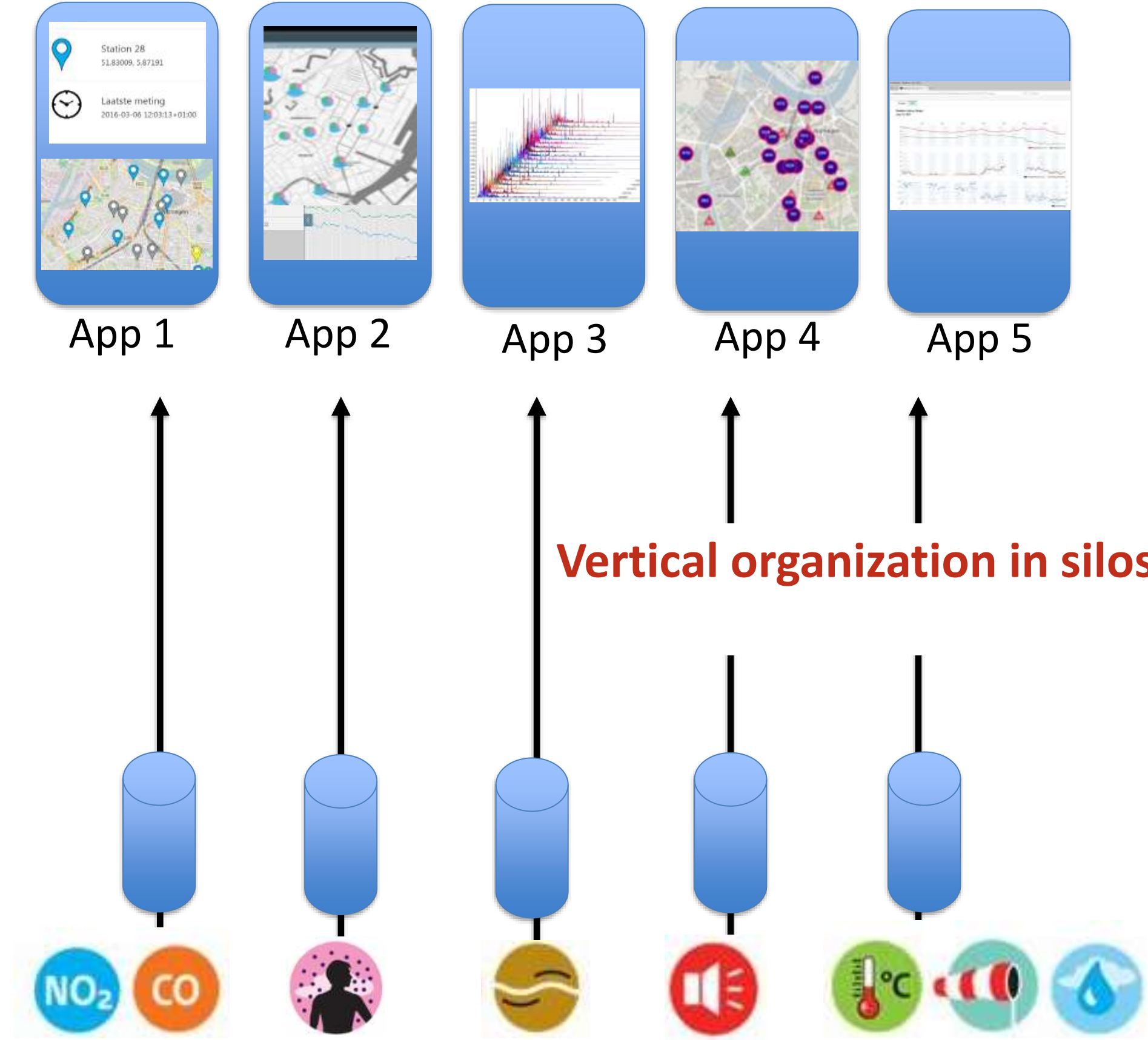
Residents can then develop scenarios based on these images to improve the air quality even more and make their local environment and the city of Nijmegen healthier.

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:

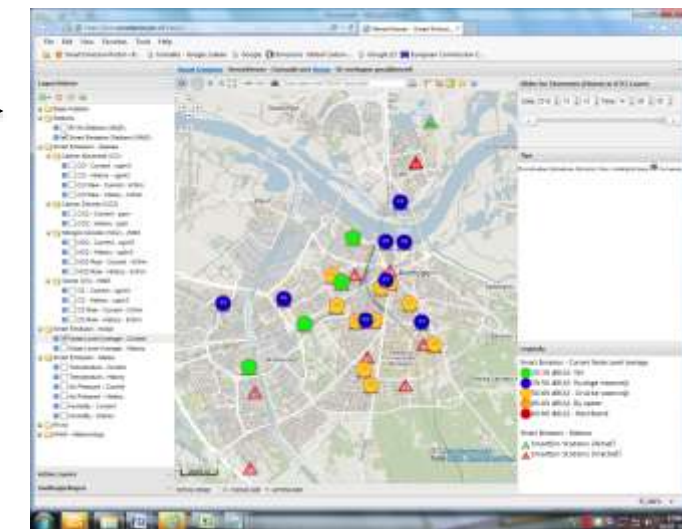
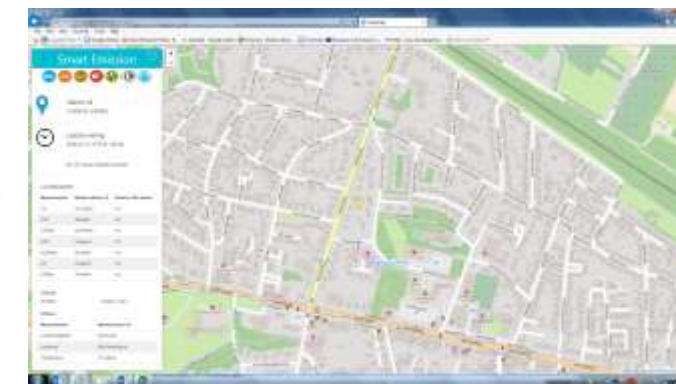
Specialize in maintaining small sensor stations in a cost-effective, efficient manner, optimizing distance-maintenance.

Coordinate the knowledge and the data chain in:

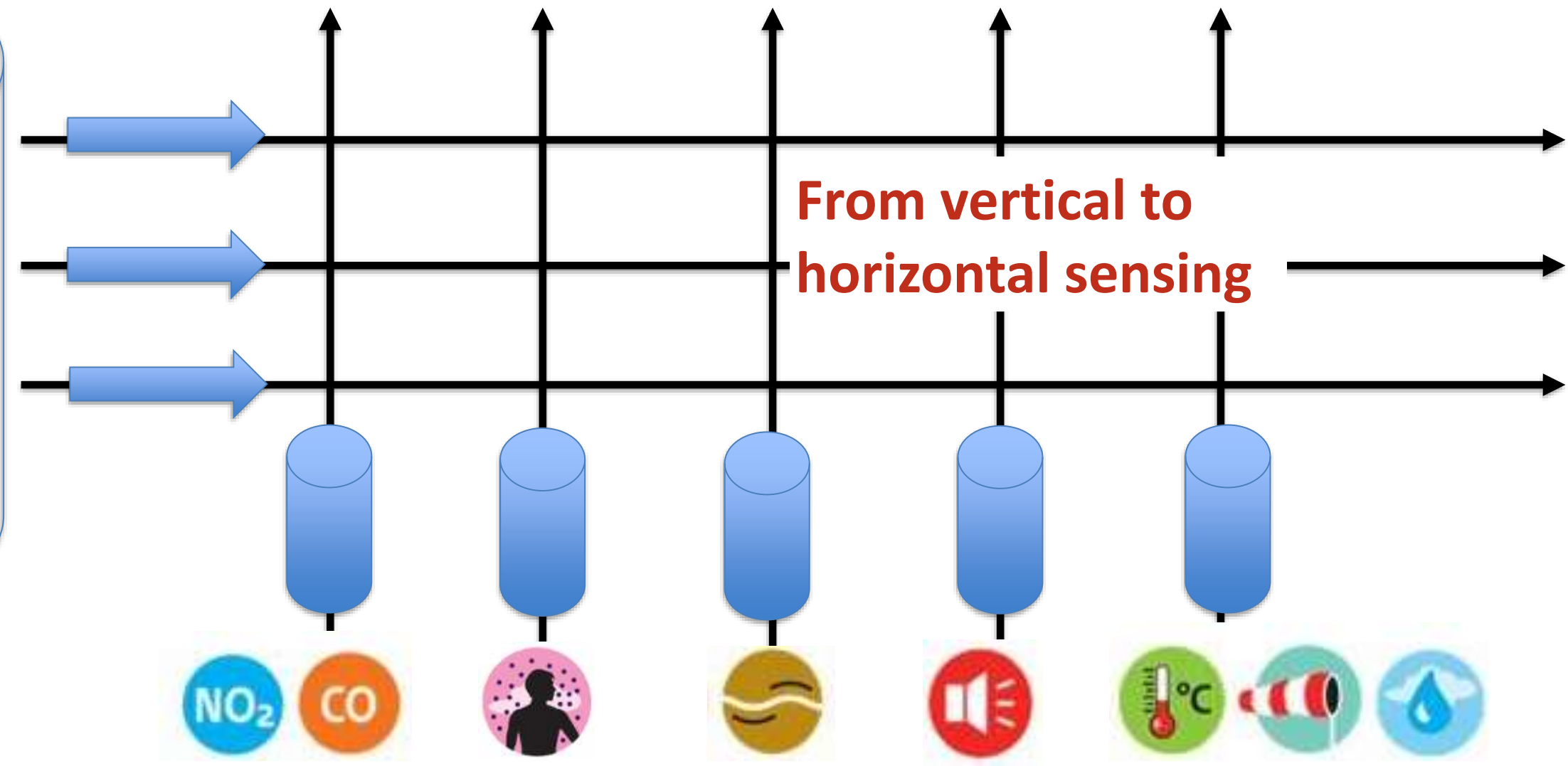
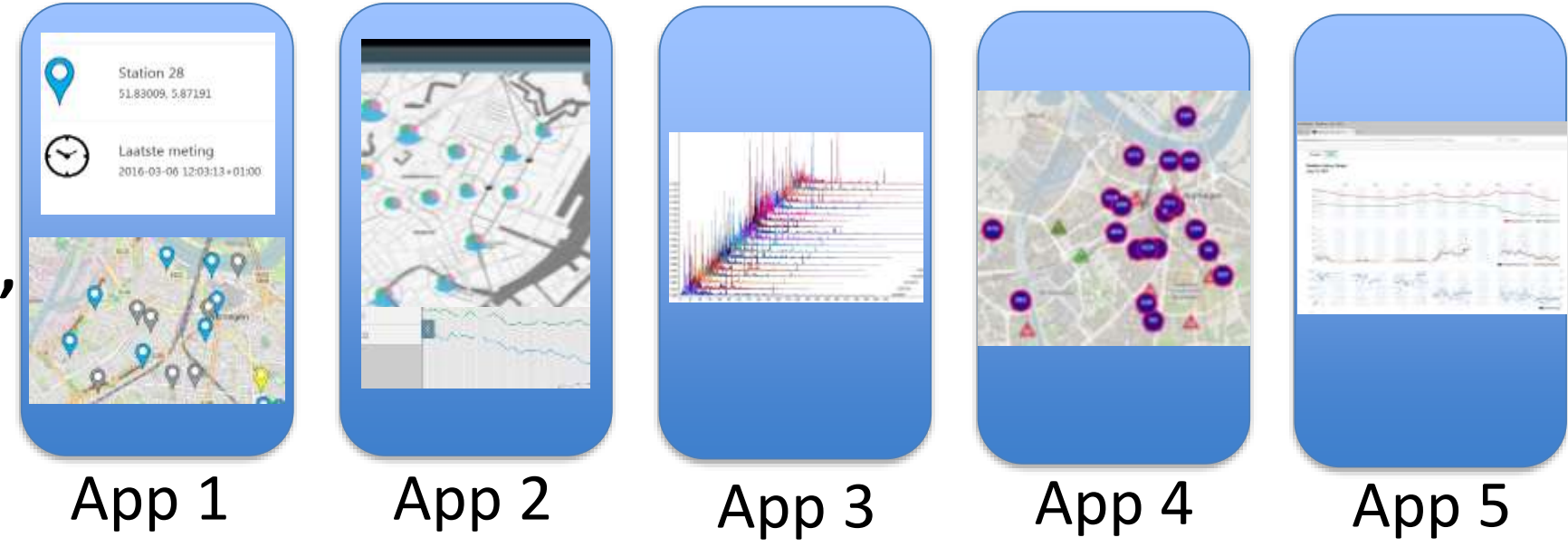
- Sensor management and maintenance
- Data management
- Sensing-specific data analytics, (automated) information analysis
- Publishing for viewing and interpreting by experts and citizens



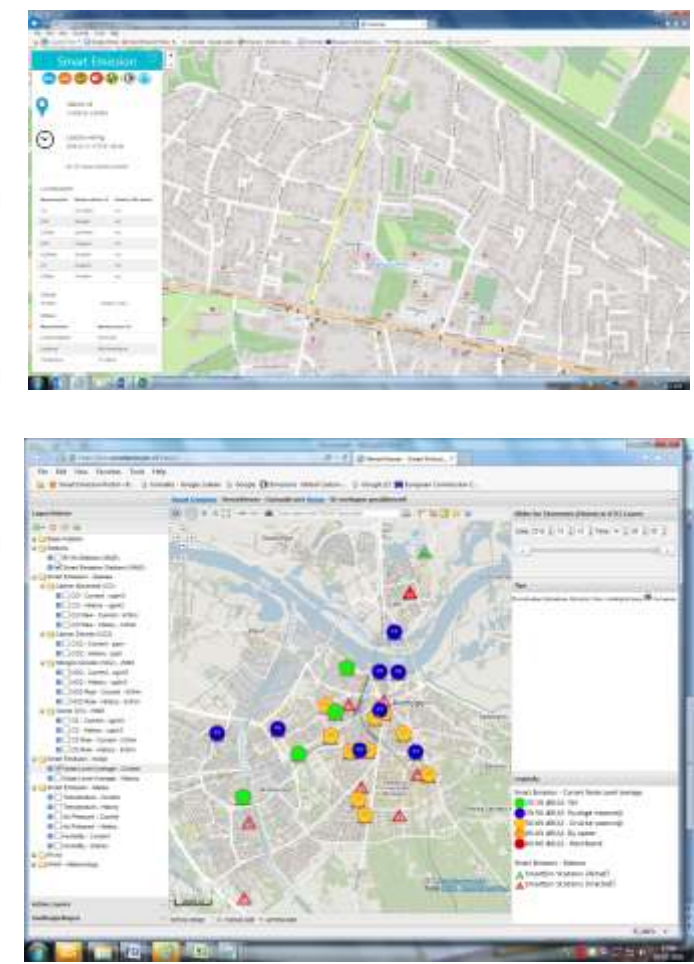
Integrated viewers



Instead of silo solutions
for every sensing sector...
create integral sensor stations,
data chain processing, and
publishing



Integrated viewers

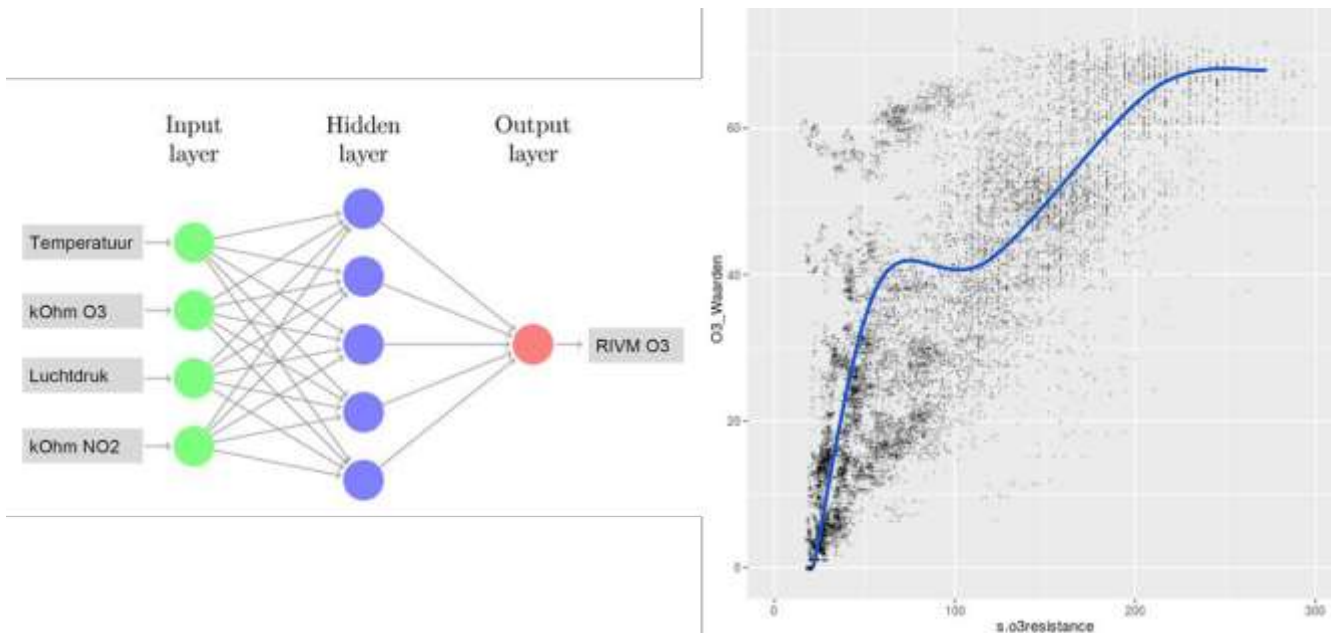


Interactive process with citizens and experts
during the pilot project 2016 – 2017, photos



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

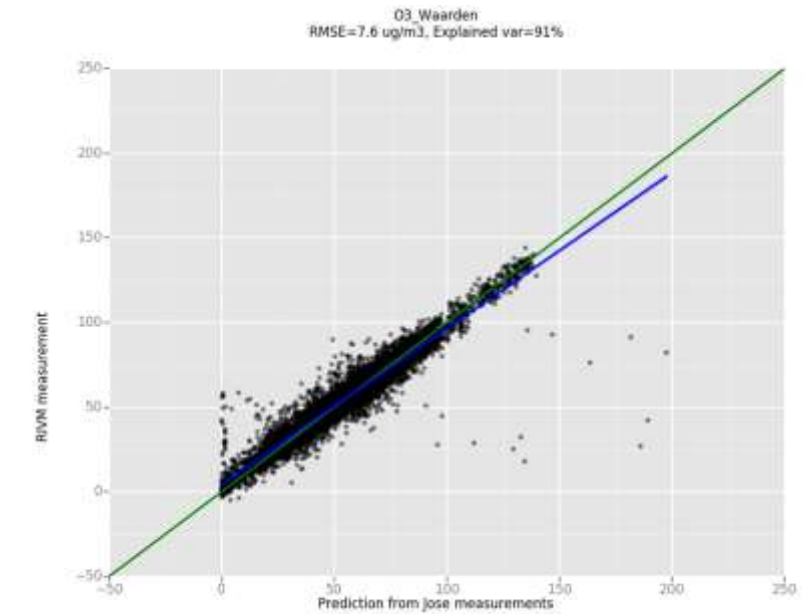
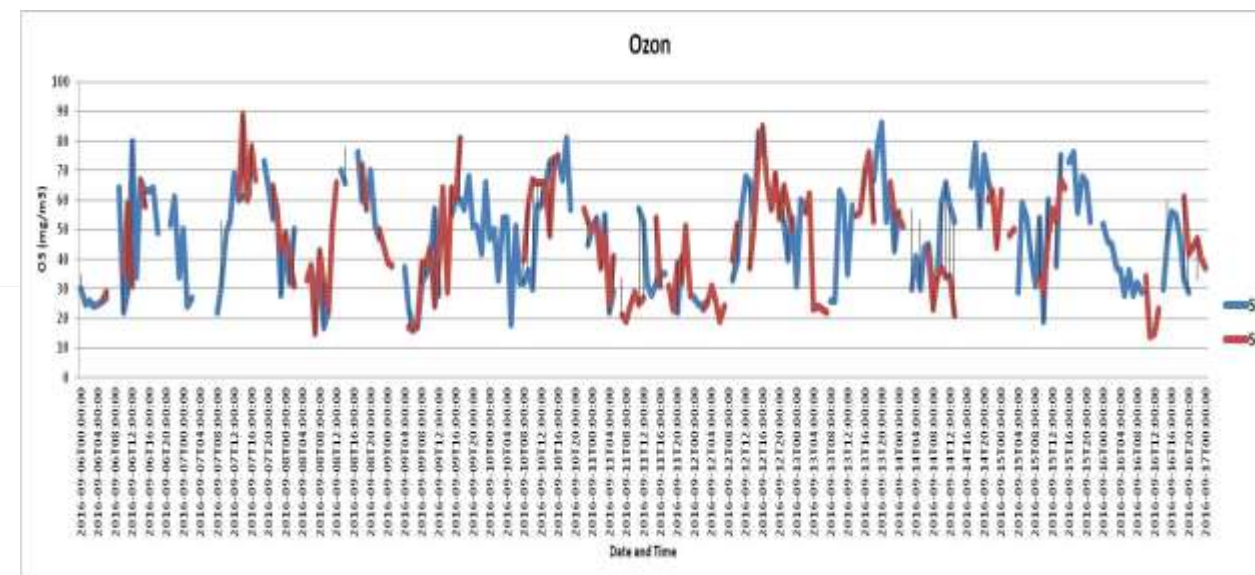
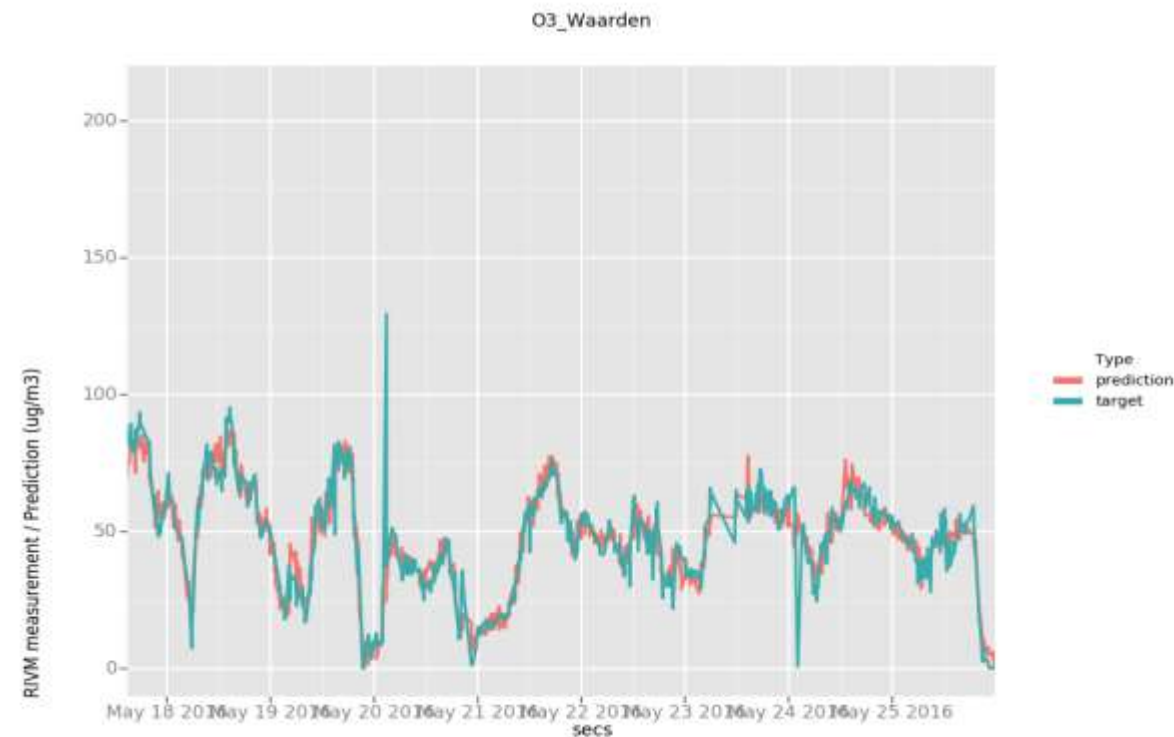


AI, neural network algorithm, training for 3 month:
Finding sensor indicators that are relevant for calibrating
ozone:

datetime
p.base.timer
p.co.heater.mode
p.co.heater.value
p.error.base irq.service.stopped
p.error.booting
p.error.configuration
p.error.memory
p.error.sensor
p.error.wifi.connection
p.no2.heater.mode
p.no2.heater.value
p.power.aux_power.input.active
p.power.charged
p.power.charging
p.power.co2.sensor.on
p.power.co.heater.on
p.power.energy.harvesting.standby
p.power.error
p.power.gauge.ok
p.power.h2s.sensor.on

p.power.harvest.input.active
p.power.mains.input.active
p.power.nh3.sensor.on
p.power.no2.heater.on
p.power.no.battery
p.power.o3.heater.on
p.power.pm.sensor.on
p.power.usb.input.active
p.session.up.time
p.total.up.time
p.unit.serial.number
p.unknown.17
p.unknown.18
p.unknown.19
s.accelero.x
s.accelero.y
s.accelero.z
s.barometer
s.co2
s.coresistance
s.humidity

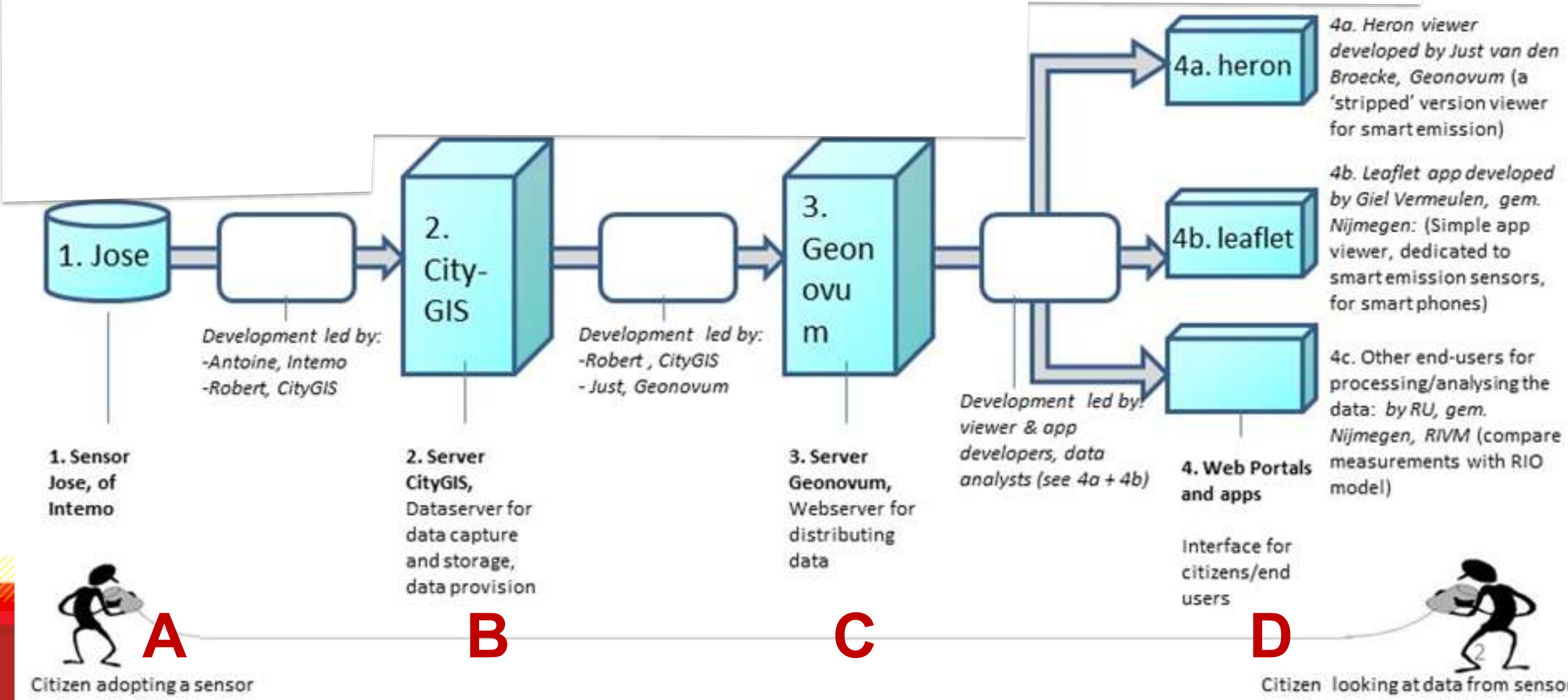
s.latitude
s.light.sensor.blue
s.light.sensor.bottom
s.light.sensor.green
s.light.sensor.red
s.light.sensor.top
s.longitude
s.no2resistance
s.o3resistance
s.rain.backside.left
s.rain.backside.right
s.rain.frontside.left
s.rain.frontside.right
s.rgb.color
s.satinfo.dilution
s.satinfo.fix
s.satinfo.num
s.second.of.day
s.temperature.ambient
s.temperature.unit



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

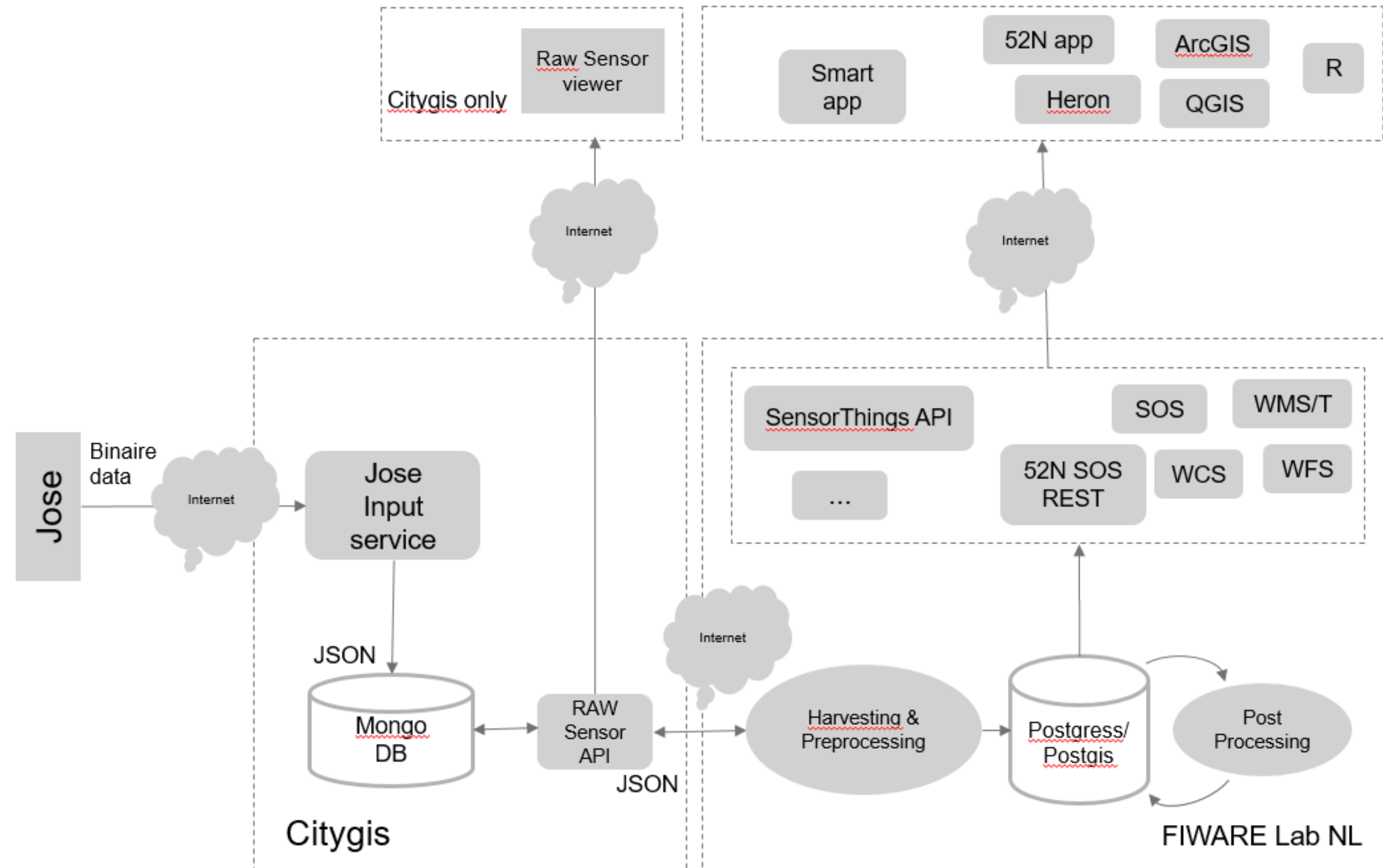
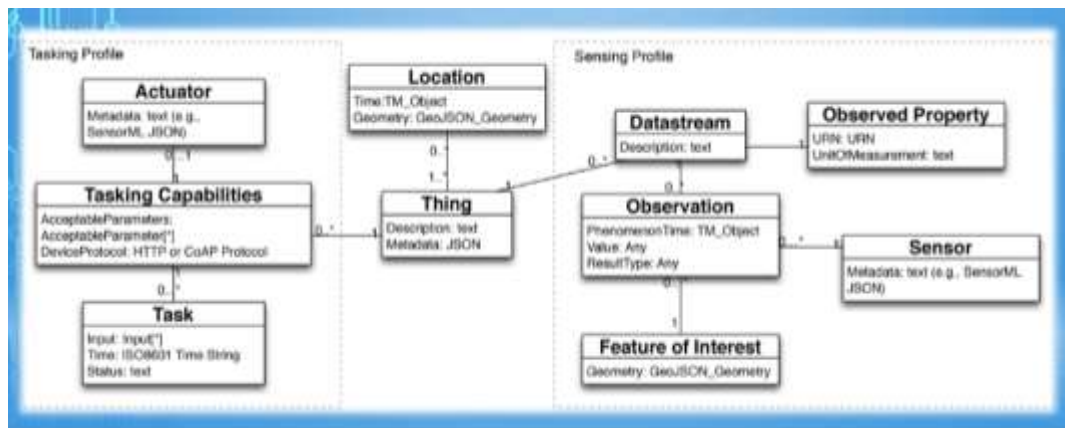
Work sketches,
communicating outline of data
chain

- 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

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

Smart Emission - Data Platform

This is the website of the Smart Emission (SE) Data Platform. This provides access to the data from the Smart Emission sensors via web services (web APIs) and a number of apps. This site and underlying services were initially developed by [Geonovum](#) in cooperation with the SE partners (see below) in the [Smart Emission Nijmegen Project](#). The platform was then further established and is used, among other things, within the [Smart City Living Lab](#) for several cities and for the [EU JRC AirSenseEUR project](#).

Mission - Mission

"The Smart Emission project revolves around the mapping of air quality, noise, vibrations and meteorological indicators in the city on a fine-grained scale, by residents with so-called citizen-sensor networks." (Source: [SE-Website](#))

Migration to Kadaster PDOK

The SE Platform is currently being migrated (2018) to the Kadaster PDOK environment.

Partners - SE Nijmegen



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



This work (website + data) comes under a [Creative Commons Attribution 3.0 Netherlands license](#).

Website made with [Bootstrap](#), [United Theme](#) and [Python Flask](#).

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.




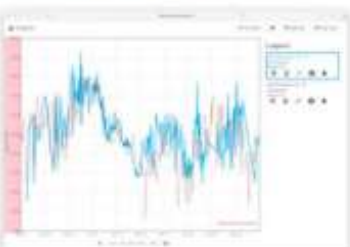

See also the [Cookbook in the SE Documentation](#) for using these APIs in clients.

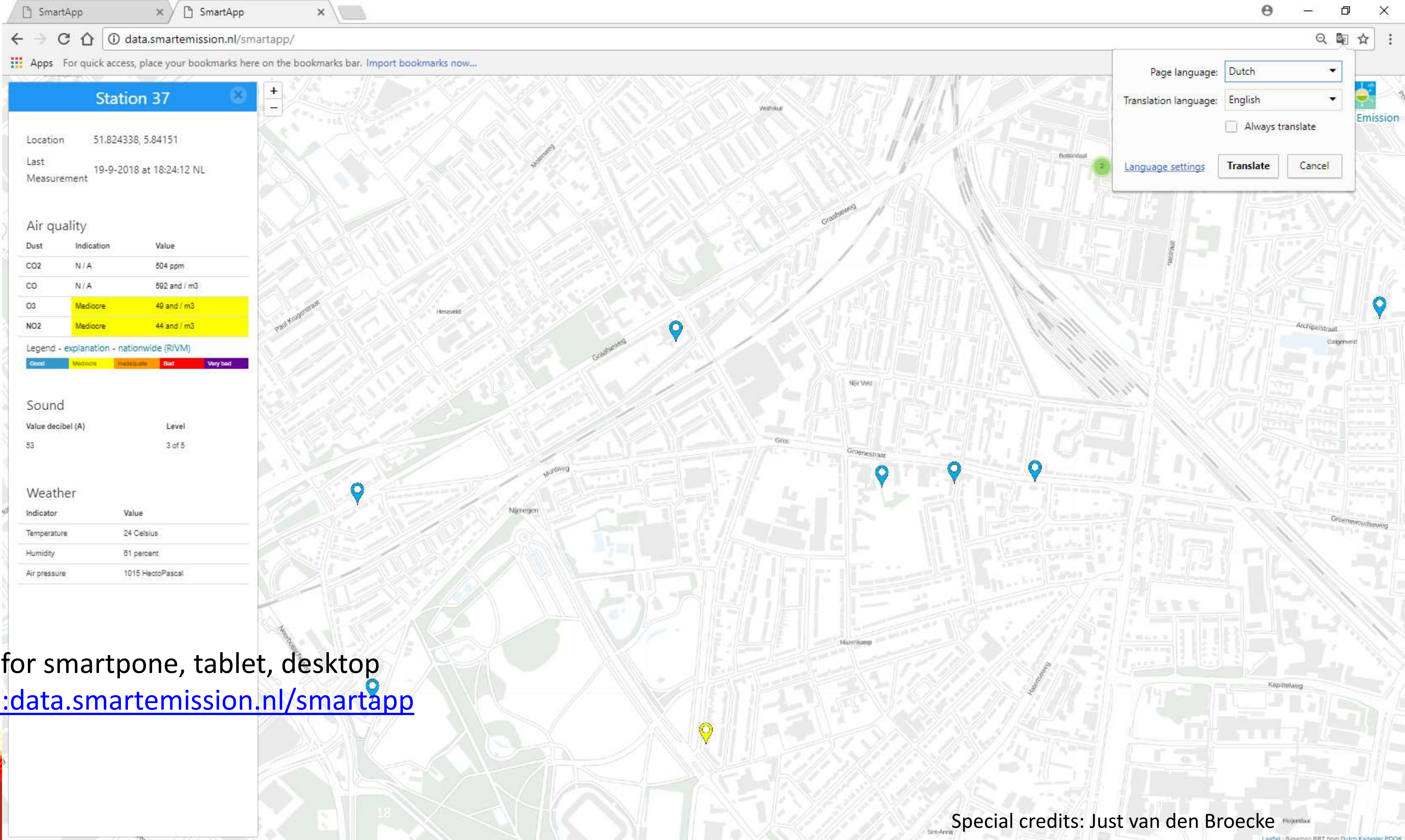
Apps and Viewers

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

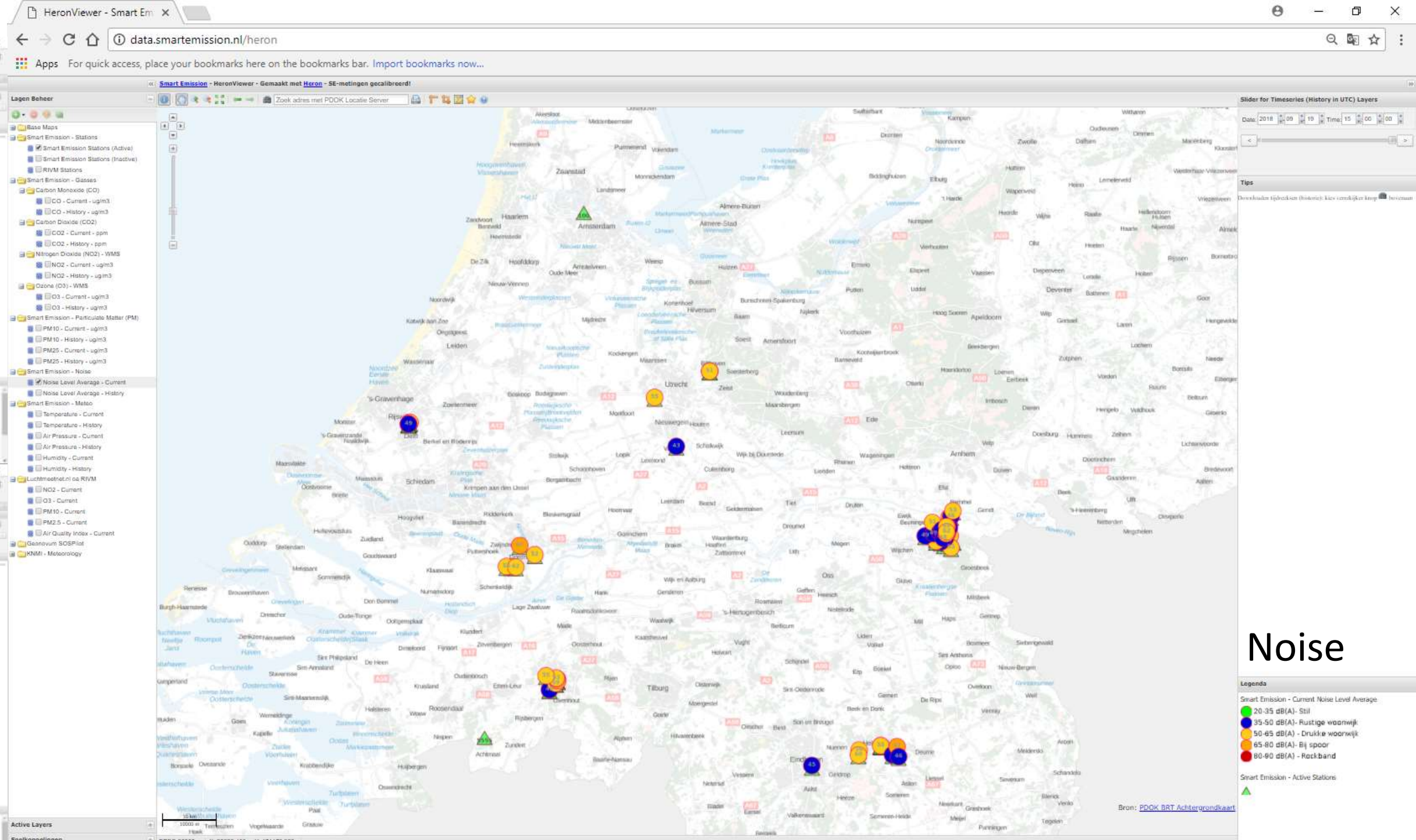
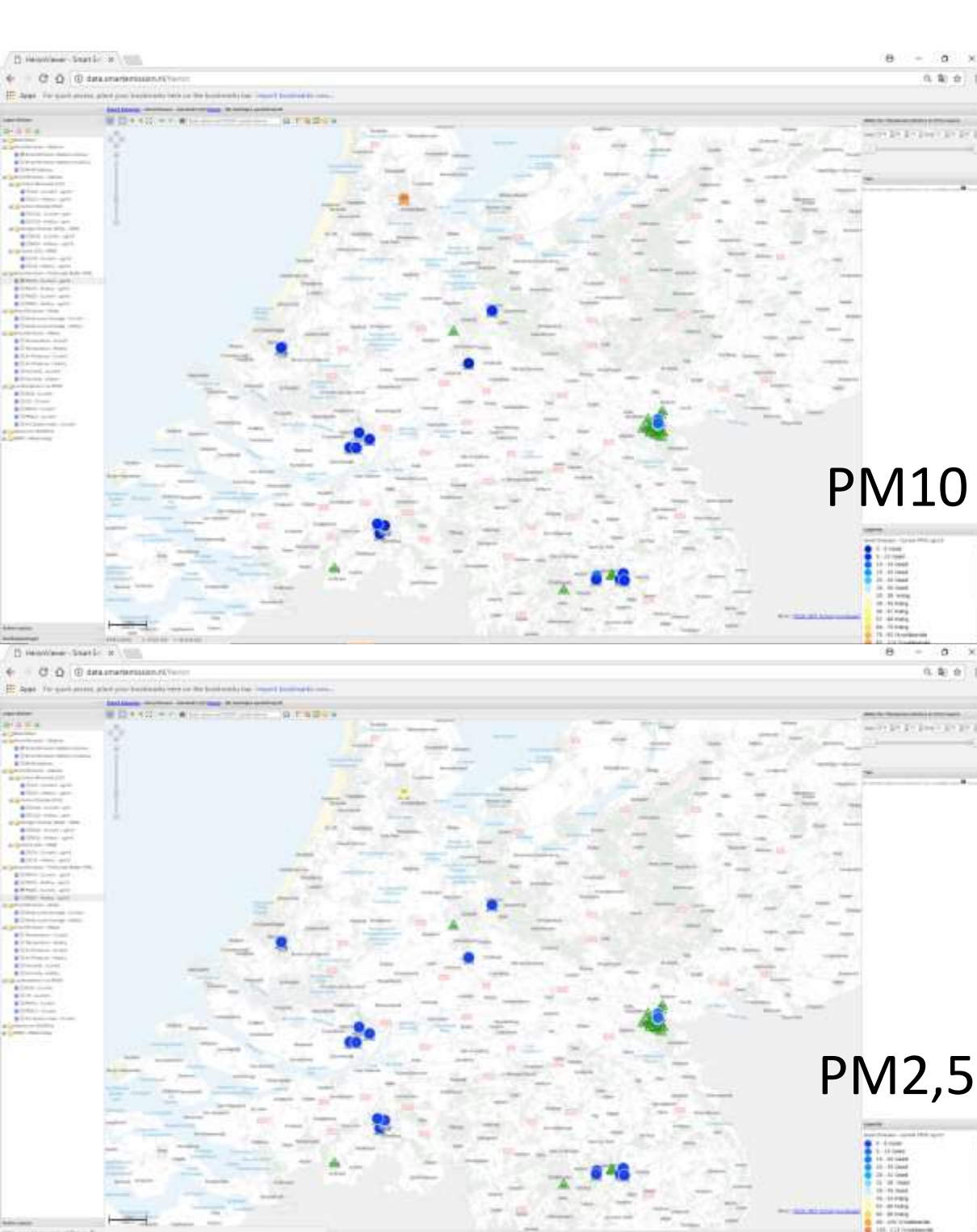
Apps developed within SE project

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)



Live, for smartpone, tablet, desktop
<https://data.smartemission.nl/smartapp>

Special credits: Just van den Broecke



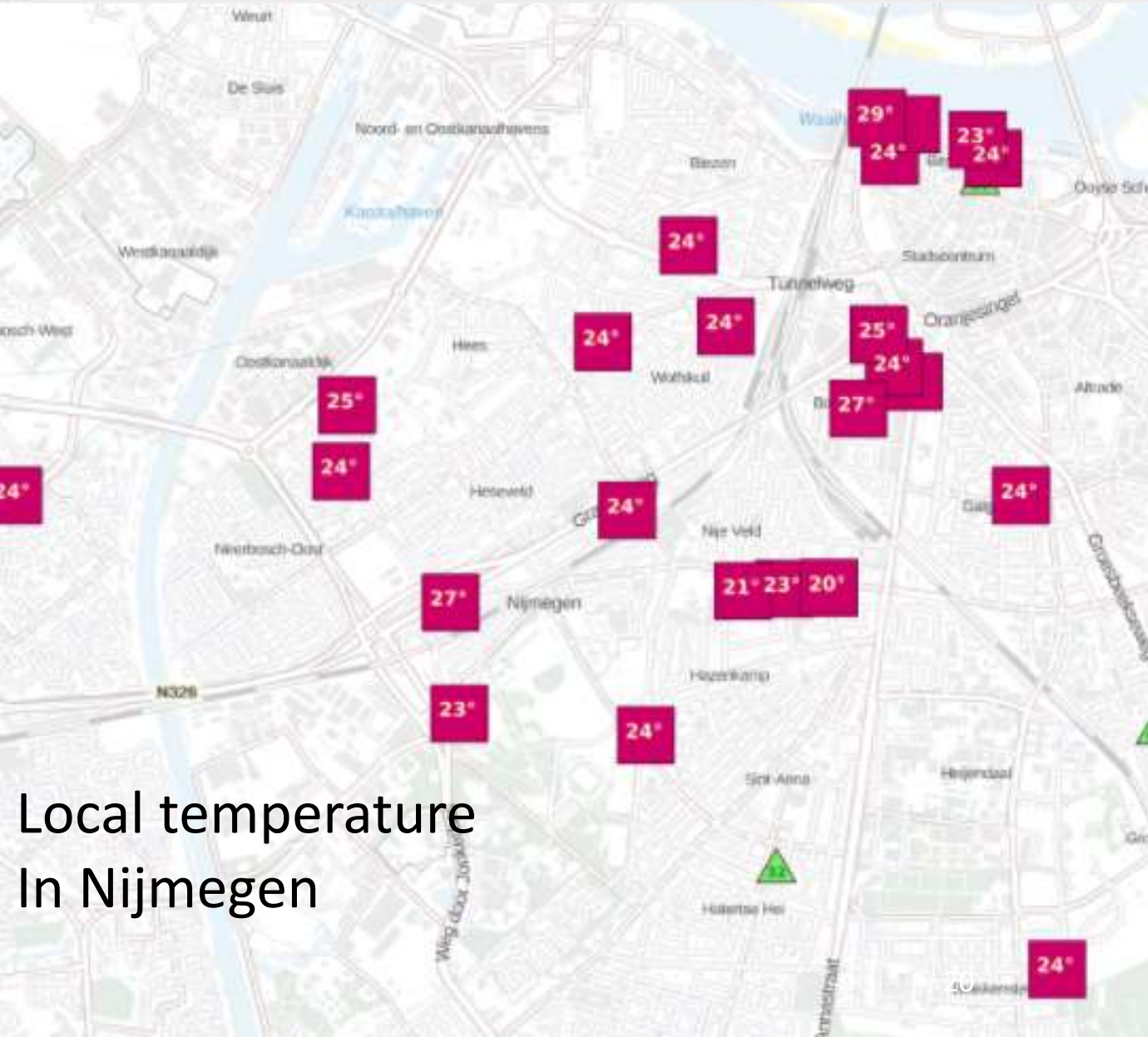
Live:

<https://data.smartemission.nl/heron>

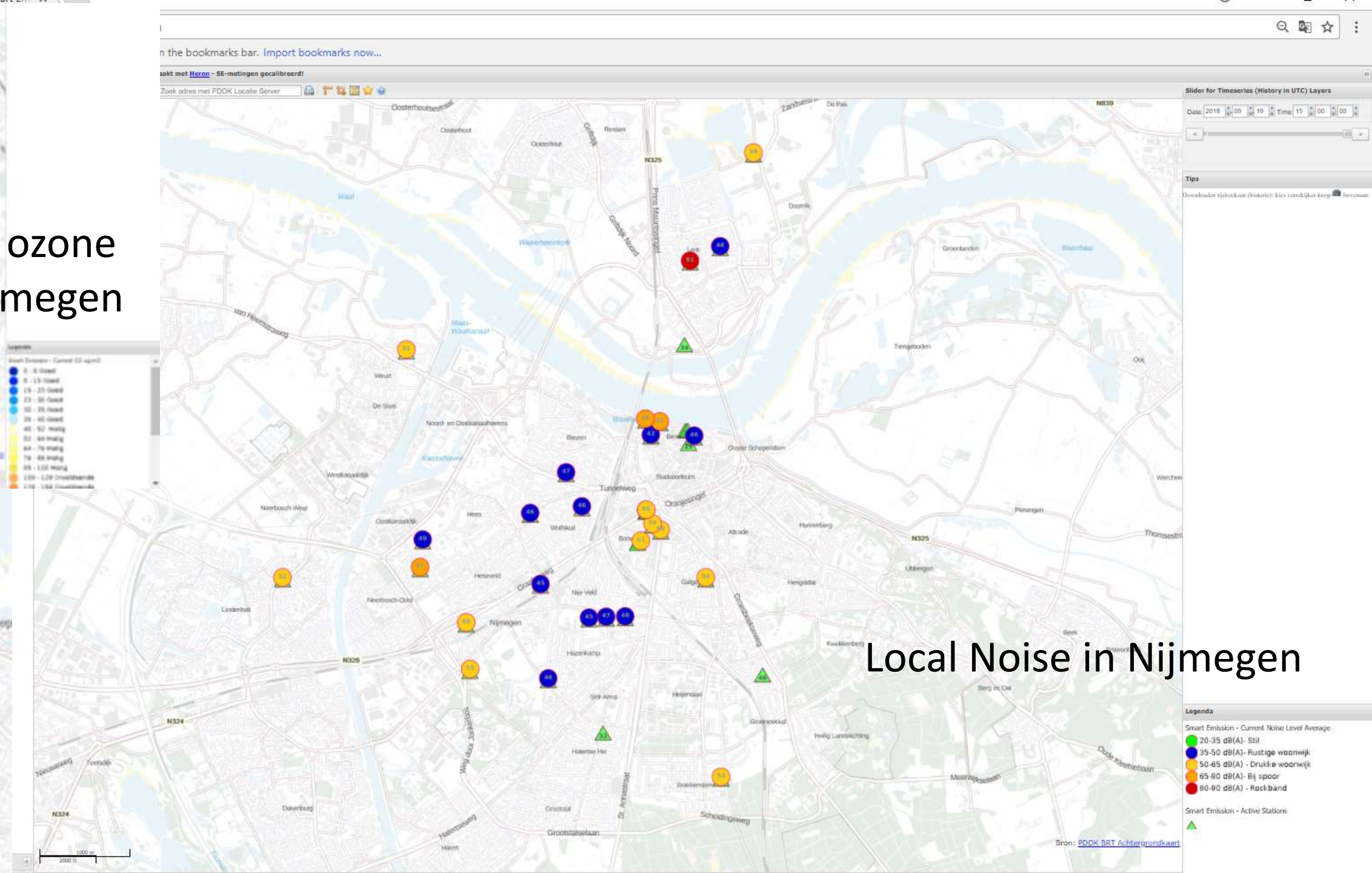
Experimental National Spatial Data Infrastructure for sensor data,
used by multiple projects: 1. Smart Emission, 2. National Smart City
Living Lab, 3. Nijmegen Green Capital Waalkade monitoring



Local ozone
In Nijmegen



Local temperature
In Nijmegen

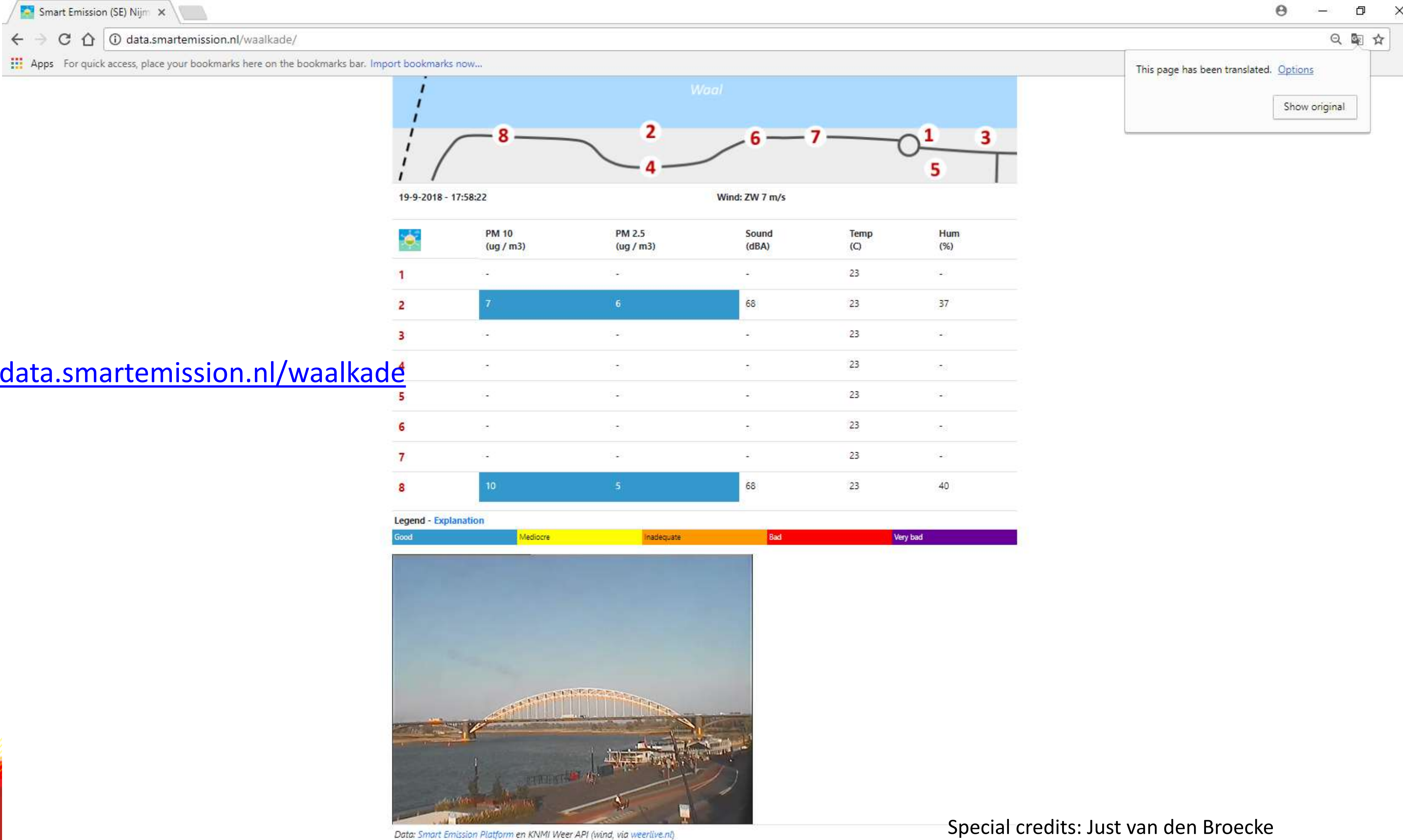


Local Noise in Nijmegen

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

Live:

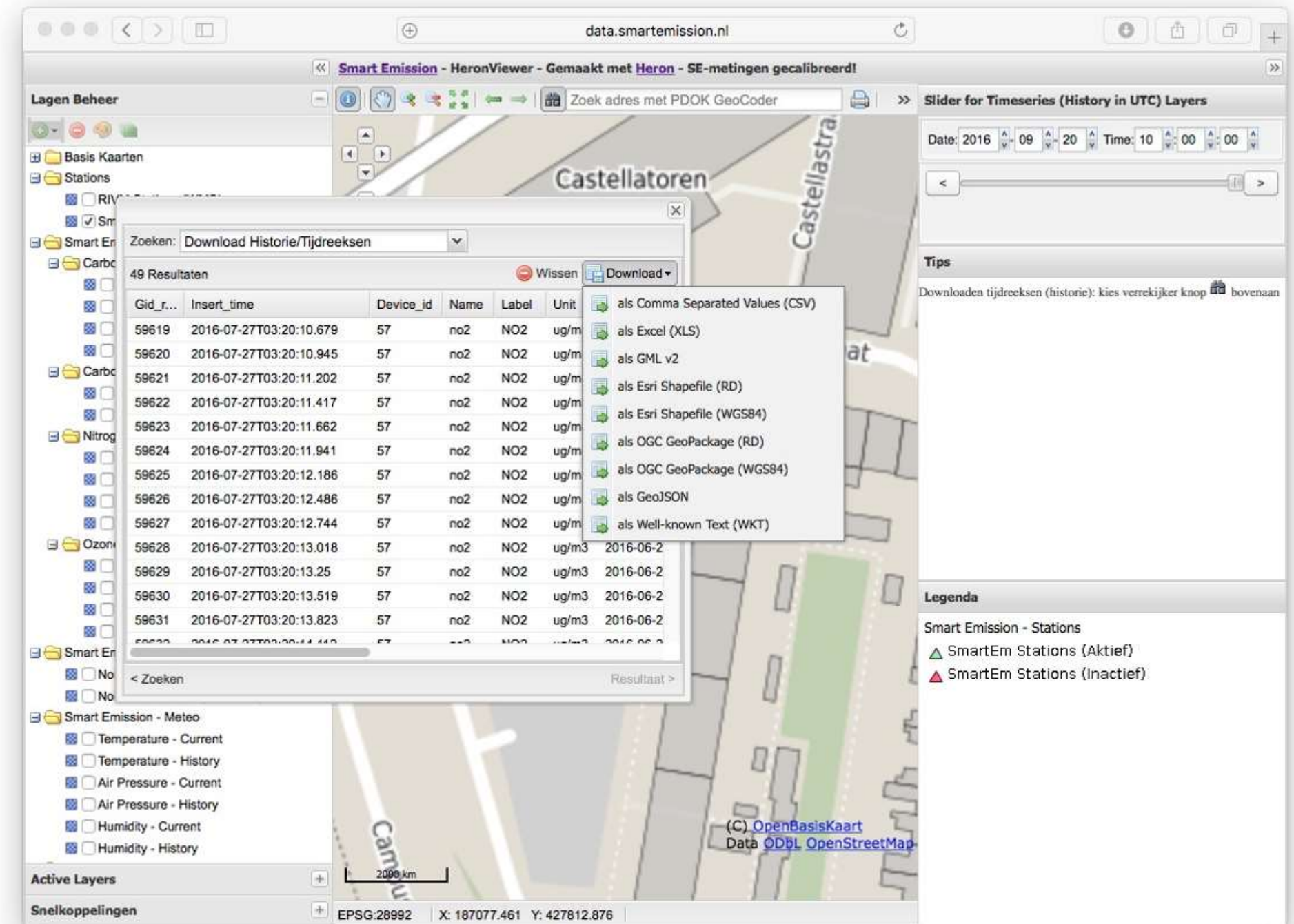
<https://data.smartemission.nl/waalkade/>



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

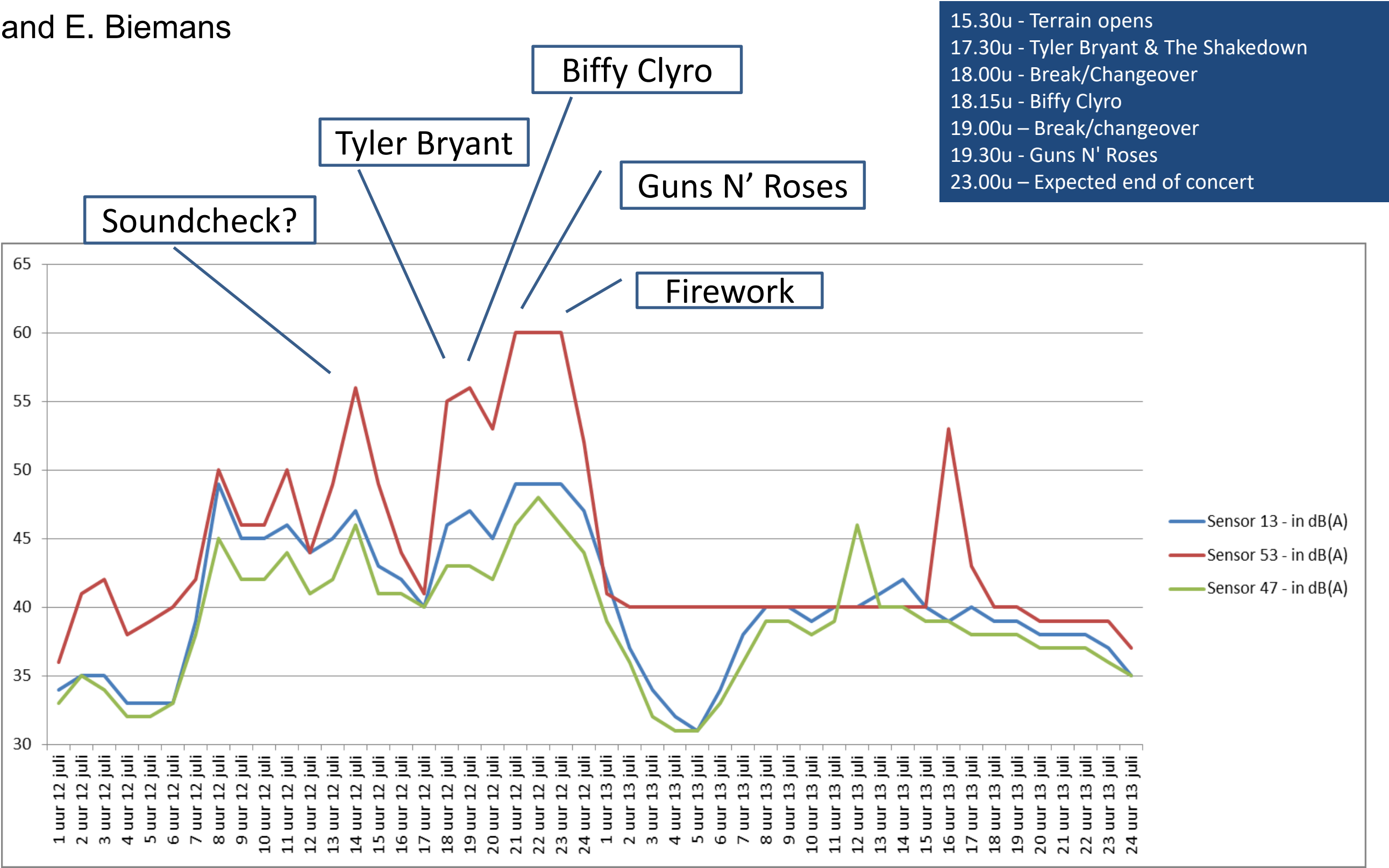


Citizen request: aggregate the timeseries based on requests to the database, when you ask for downloading:
Create Timeseries with scalable range/smallest unit (day/minute-averages), (week/hour averages)

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

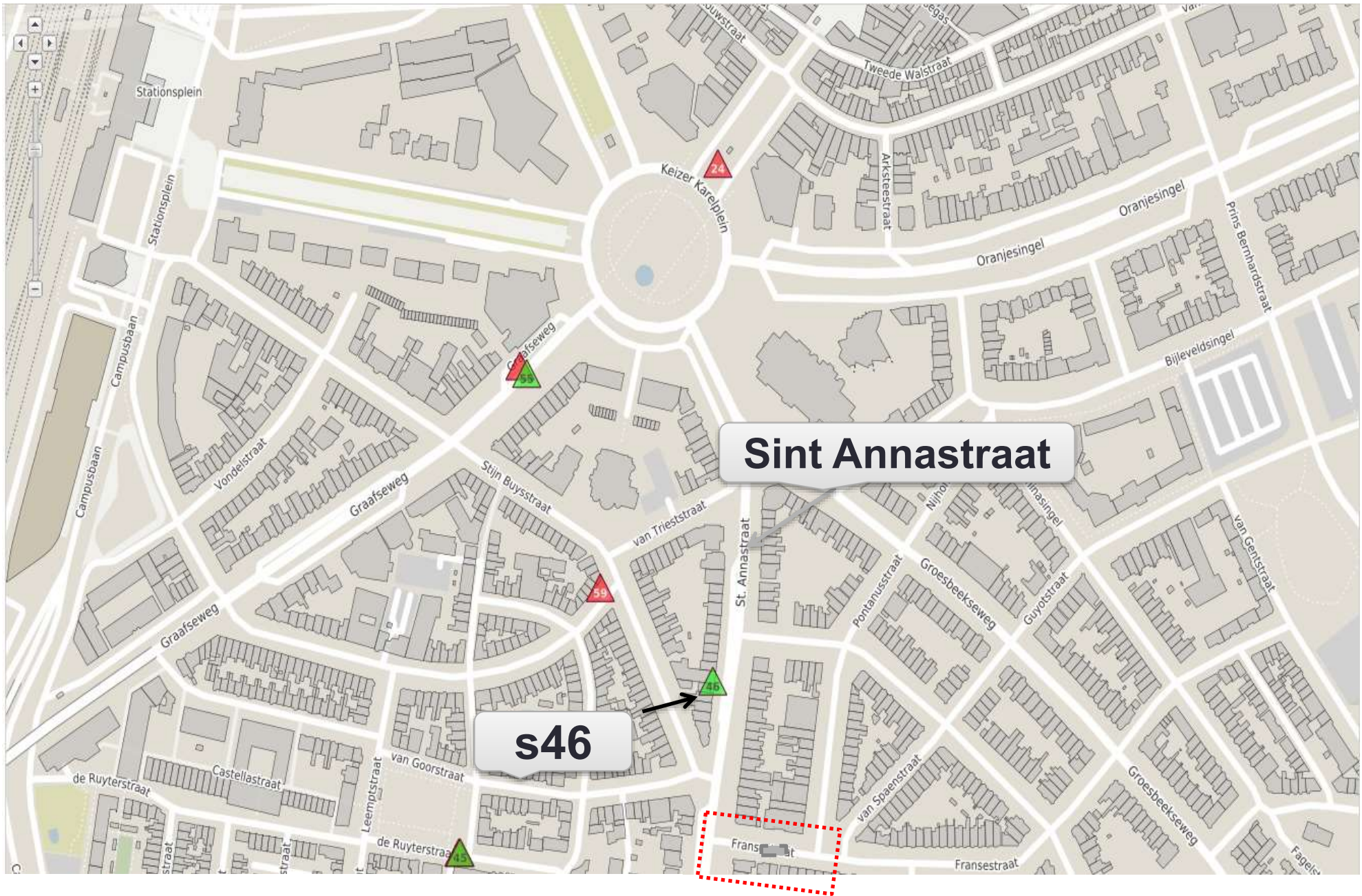
P. Biemans and E. Biemans



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 until 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)

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

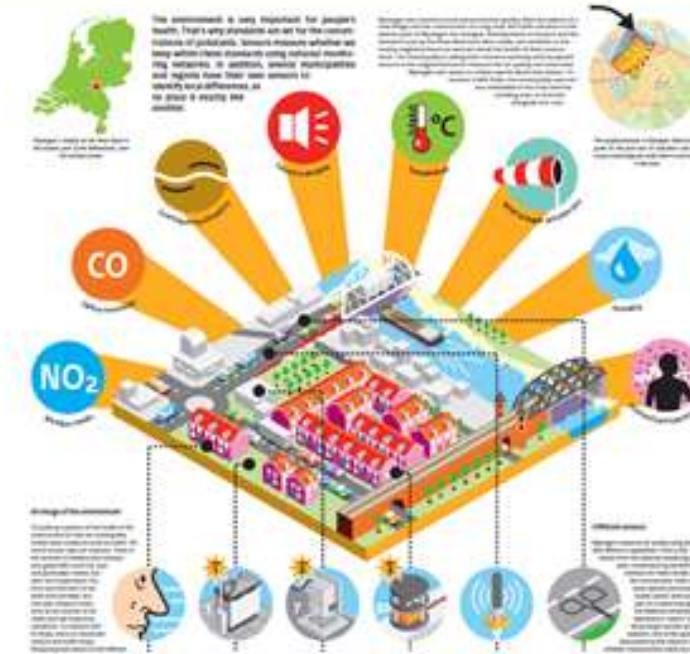
After closure of the Smart Emission project, no budget left for maintaining the data platform.

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)

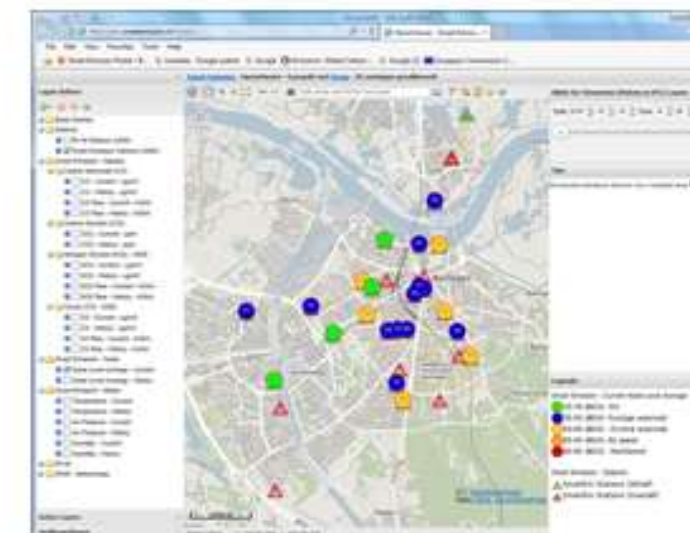
Typical valorization gap: investment subsidy for small pilot, no attention for follow-up.

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.



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').



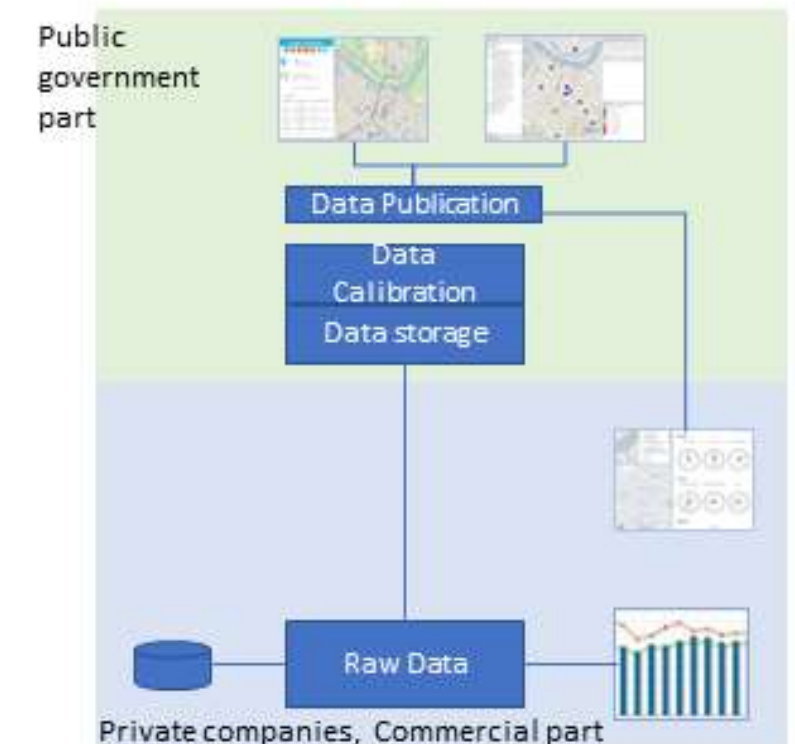
Info about the Smart Emission Data Platform

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 "citizensensorworkgroup 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

Governments interest



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

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 neighbourhood?

Companies interest



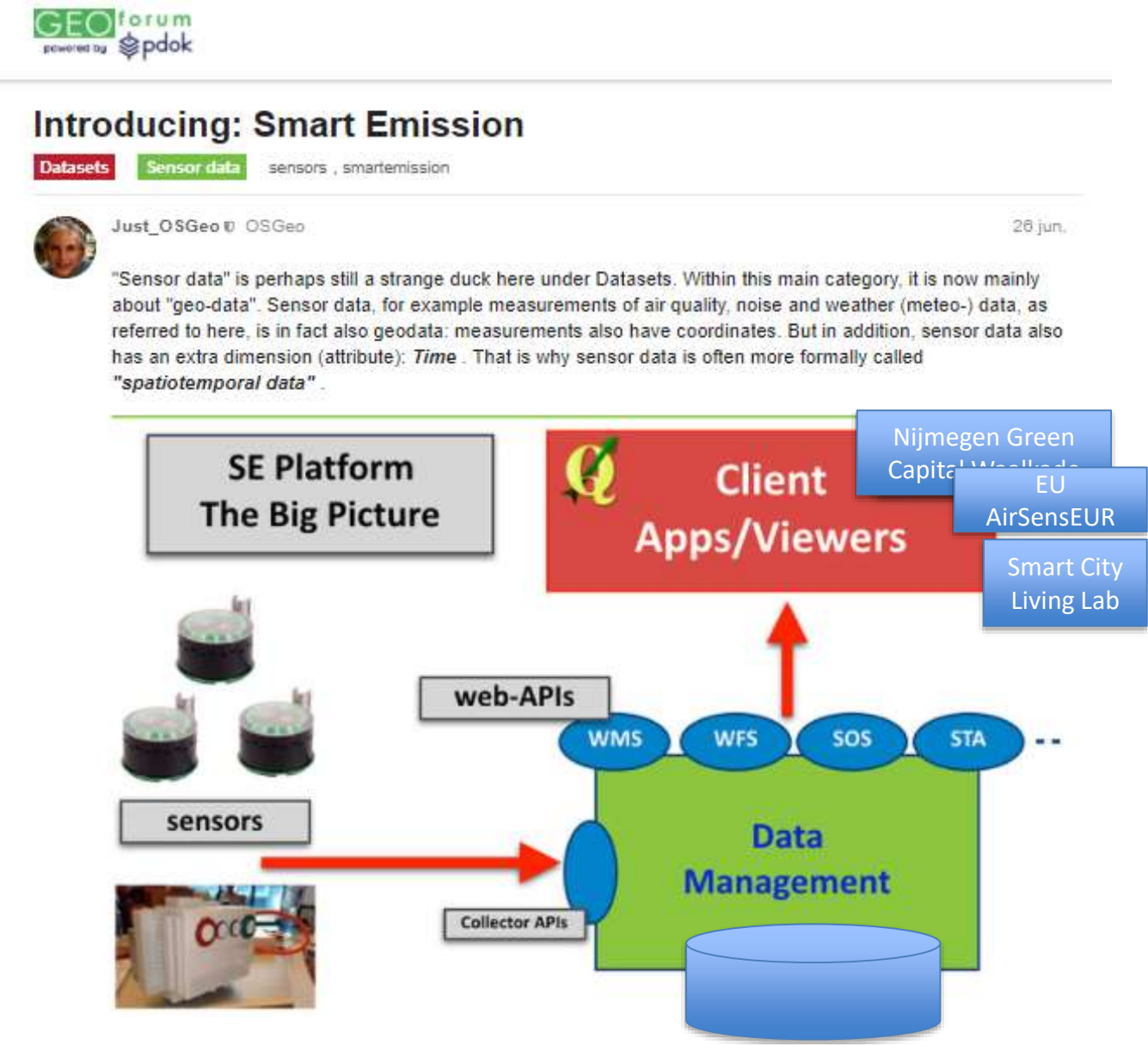
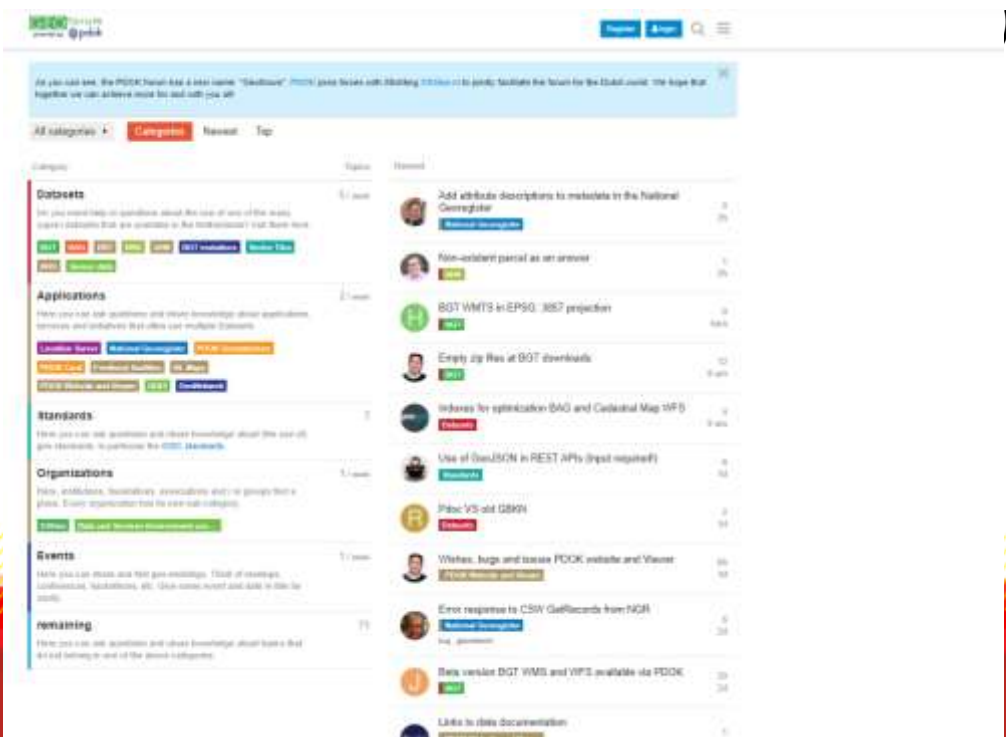
- I want to be transparent about the location of my sensors and what they do
- I want to make use of sensor data but I don't want to invest in sensors myself
- I want to use sensor data to implement new services and products

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.



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*, ECSCA 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

- TOMORROW, 13:00: 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, PM_{2,5}, 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 preventing heat stress and safeguarding health.

***Governments: Act as orchestra,
citizens make the music***

Greening the city and its advantages (Master thesis Anouk Ruijters)

