DASYA
Data-Intensive Systems and Applications

Introduction to

Air Quality Citizen Science

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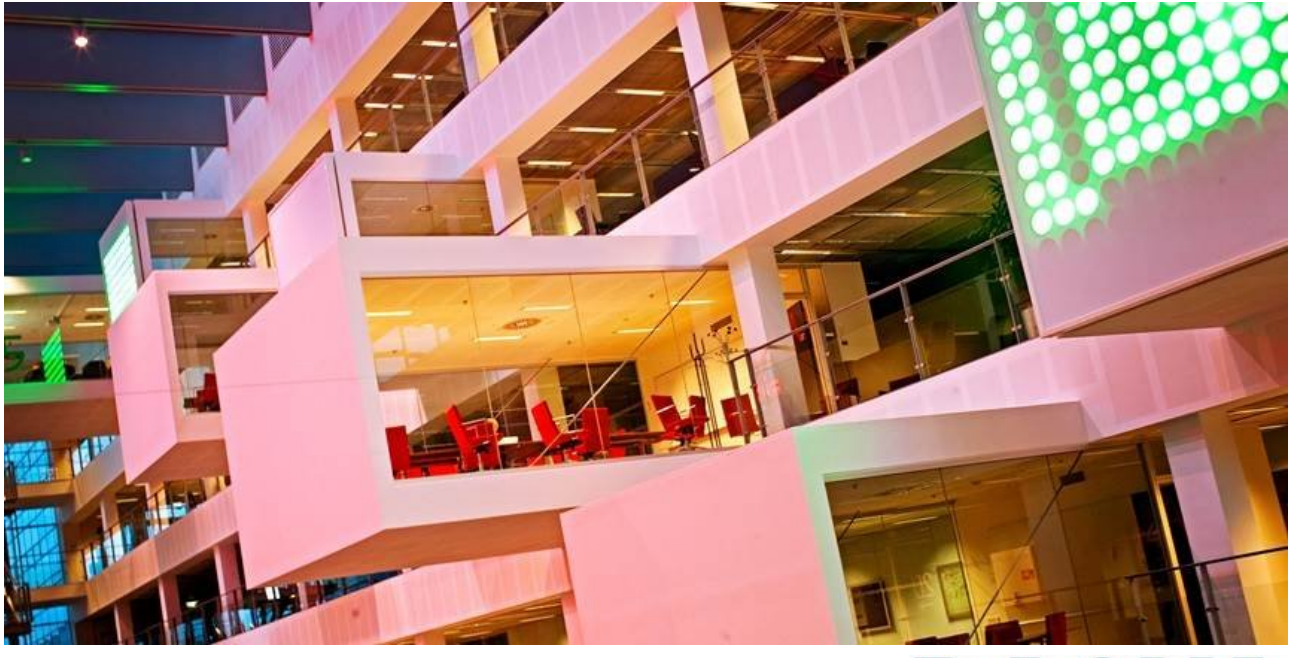
ICTP **15 March 2021**
Citizen Science with Application to Nuclear, Seismic and Air Quality Monitoring: Applications

IT University of Copenhagen

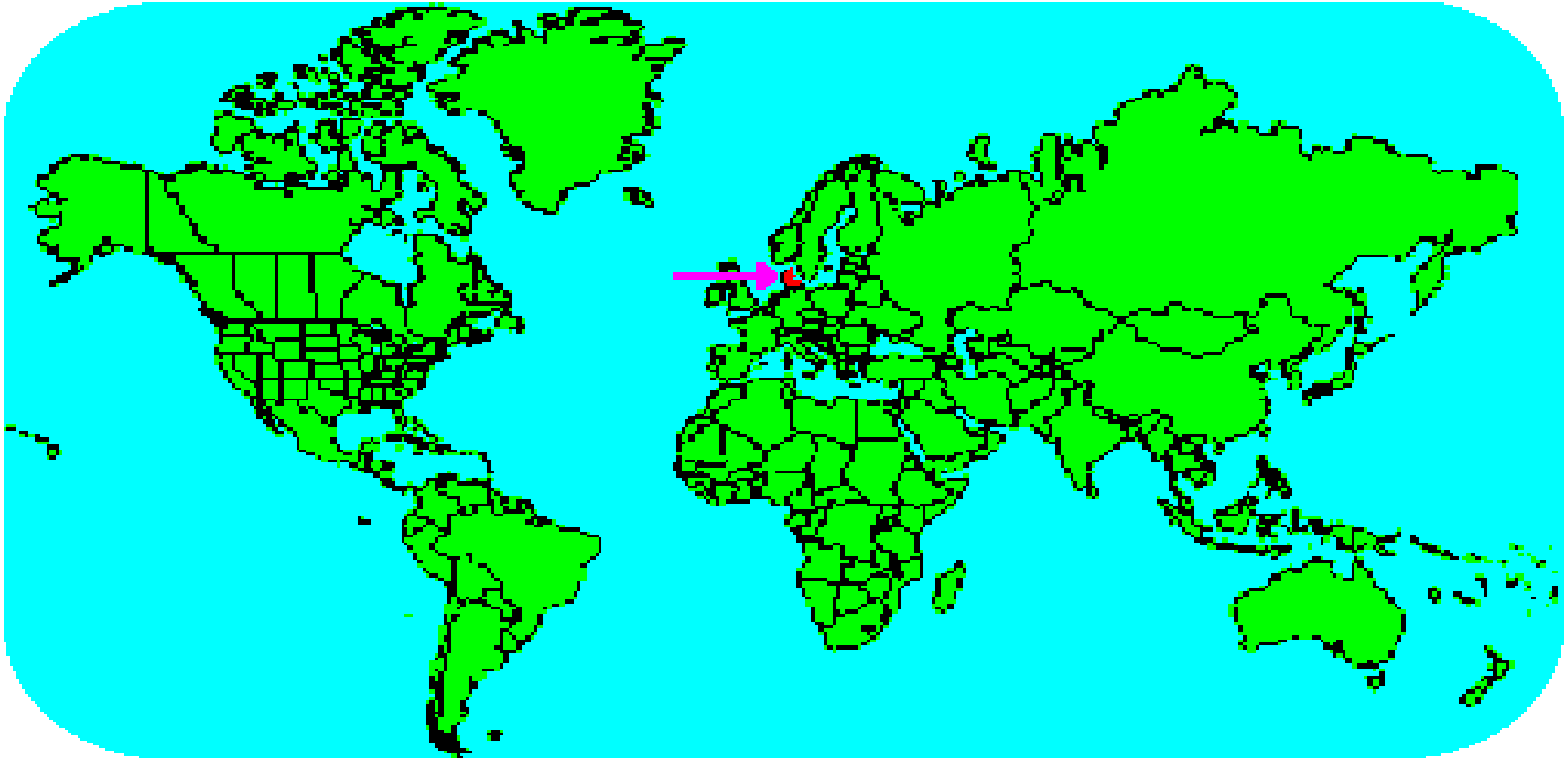
Denmark

Youngest and smallest University in tiny Denmark, but largest number of MSc candidates in Computer Science. We do **IT only!**



Denmark:
5.8 million pop.

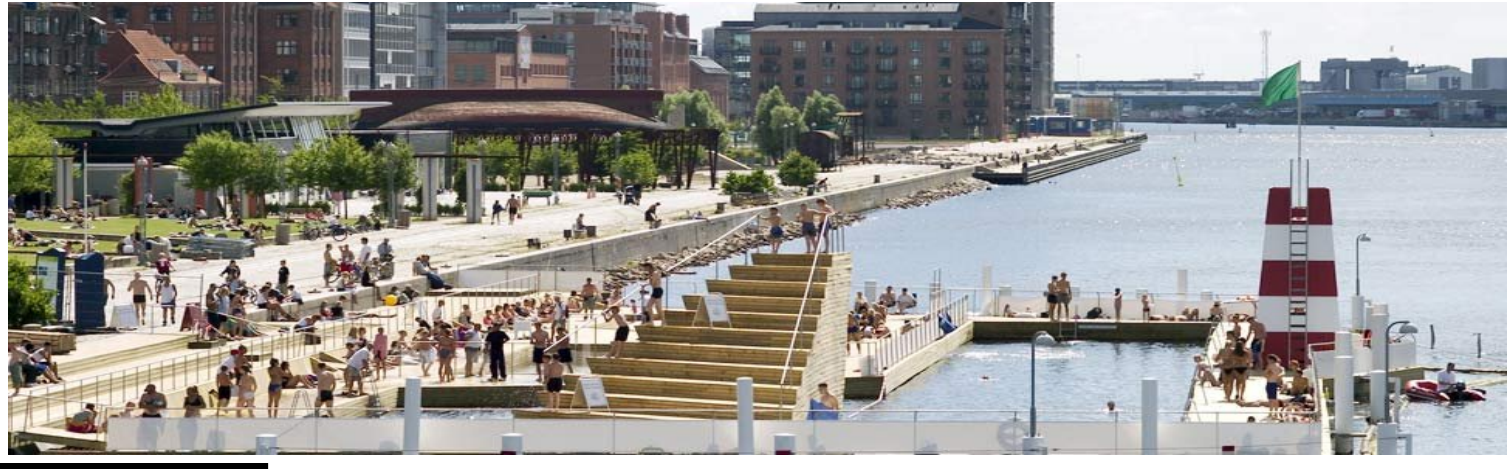
Meet Denmark



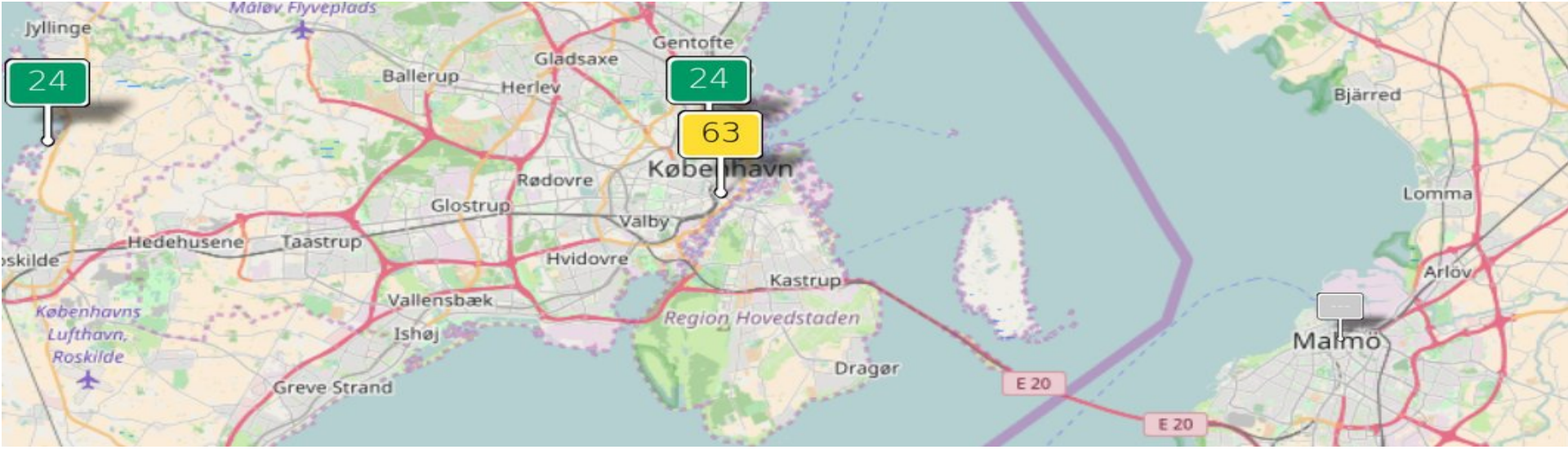
Meet Denmark

Meet Denmark

Meet Denmark

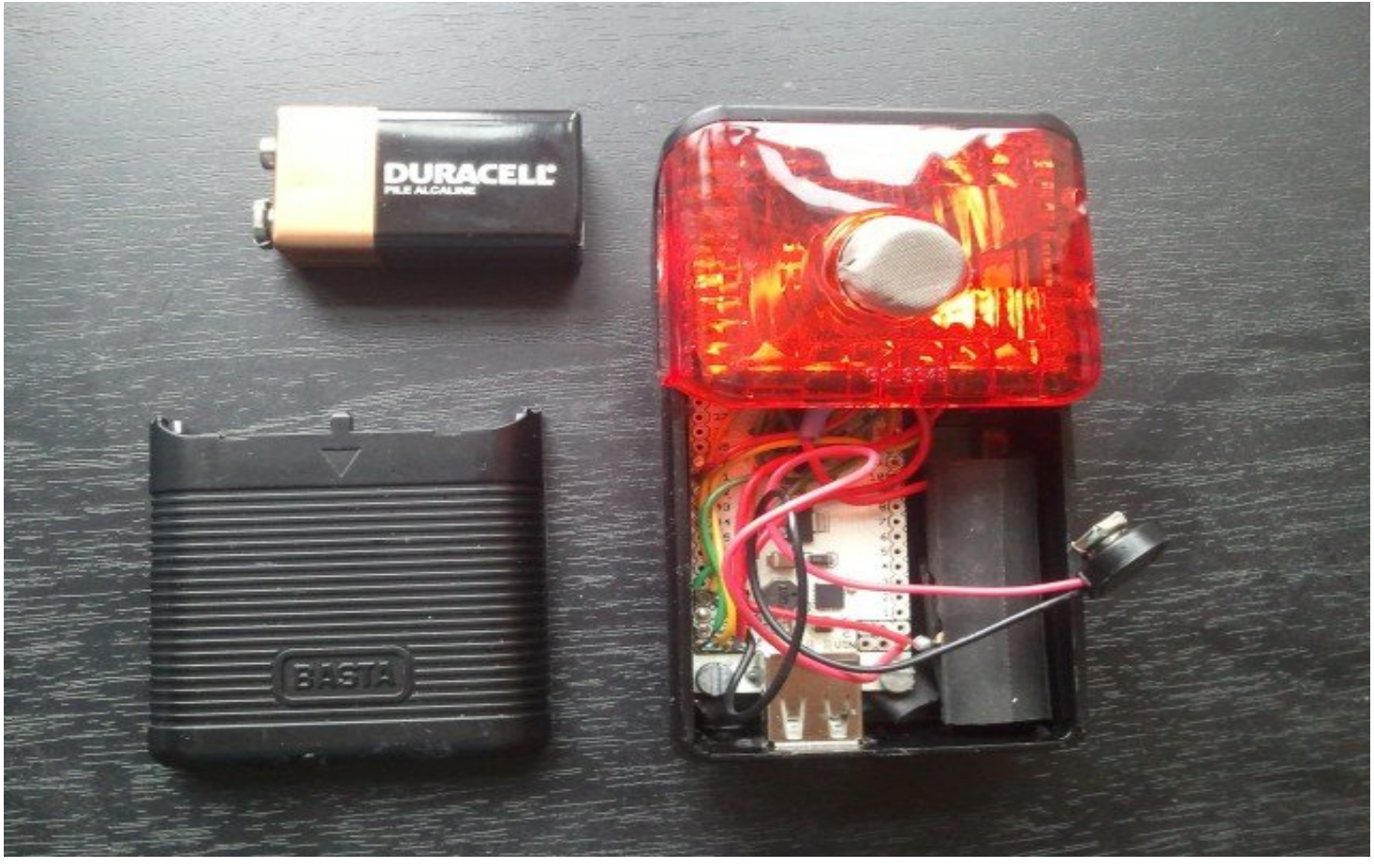


But not all is green in Denmark ..



So we biked out … project NOXDroid 2011

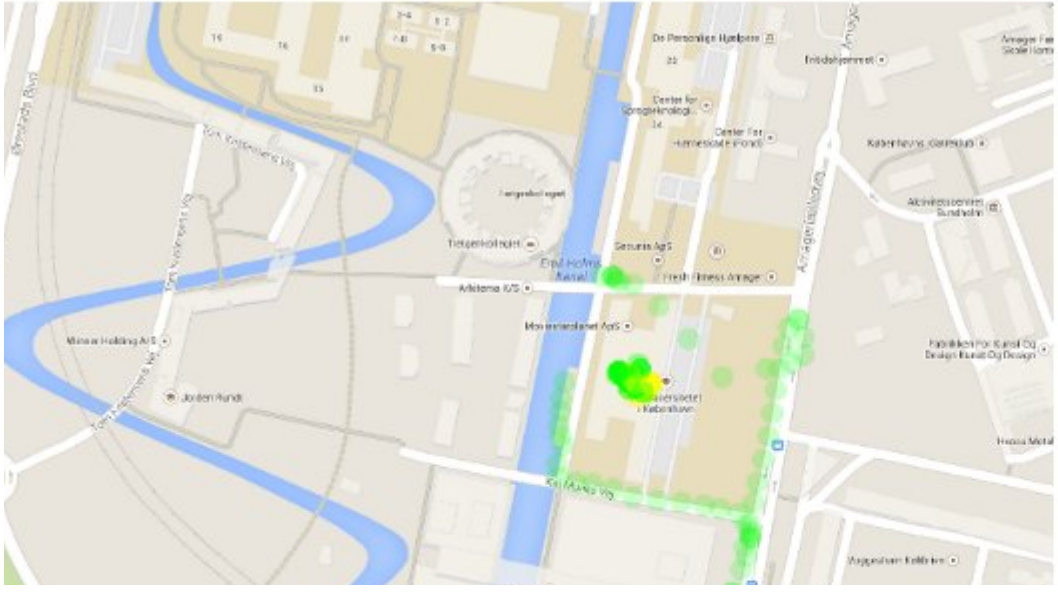
project NOXDroid 2011



project NOXDroid 2011

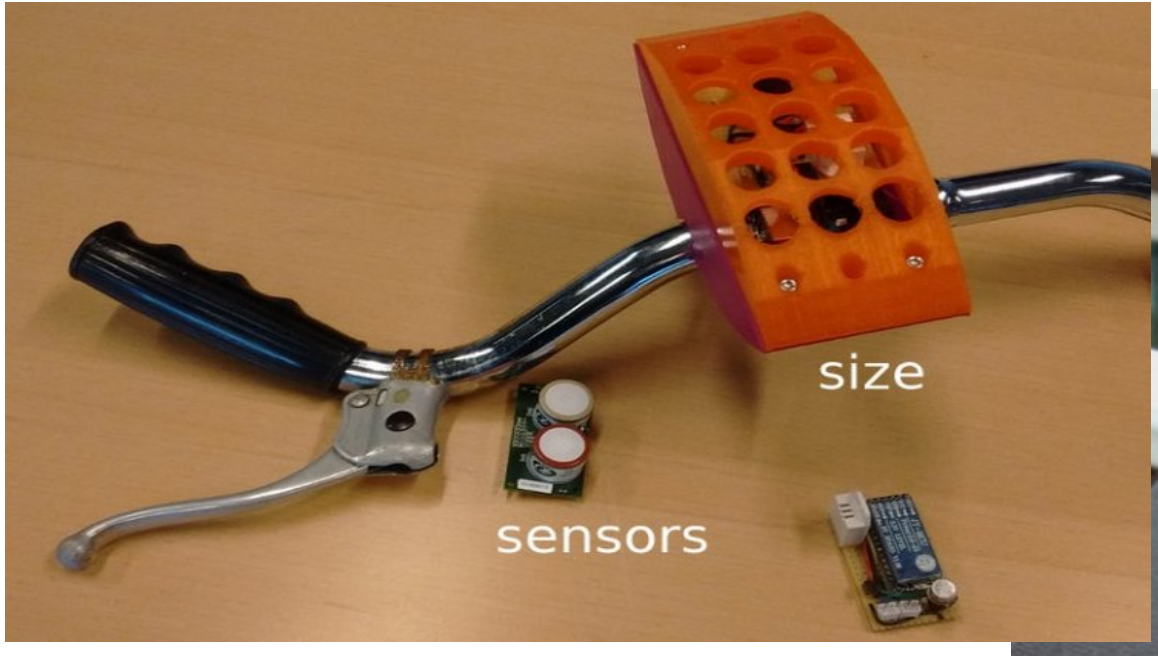
project bAir 2013

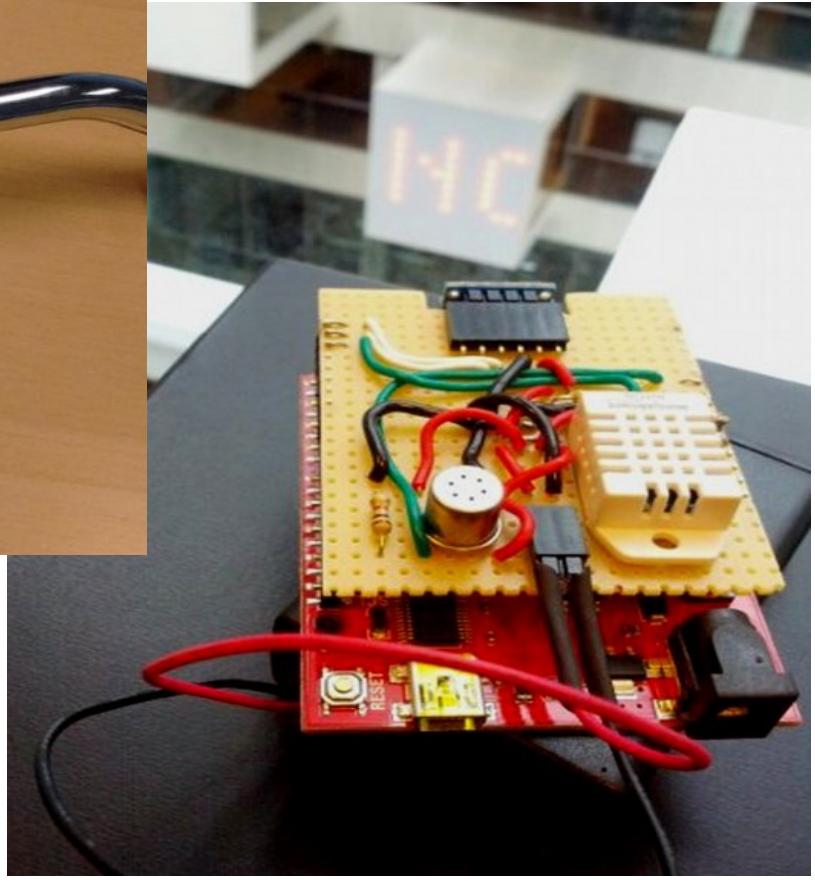
bAIR
the air bike



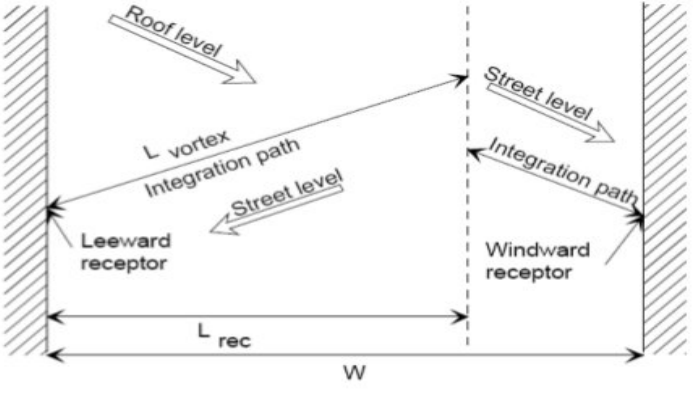
Air Qual. - RI TGS 2600		Sound L Phone Mi
Avg 437	Peak 439	Avg 52
25 Air humidity - RI RHT03		9 CO Ga TGS2
Avg 34	Peak 43	Avg 97

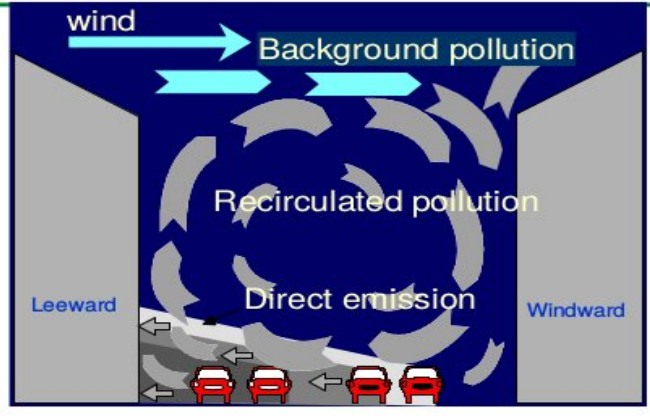
project bAir 2013

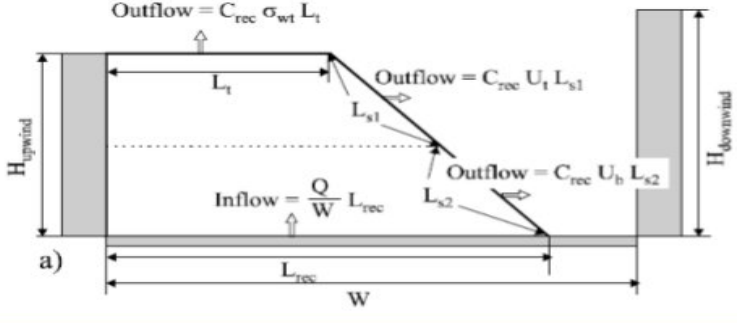


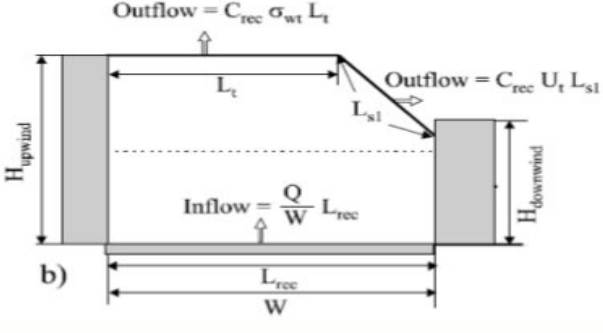


Urban modeling

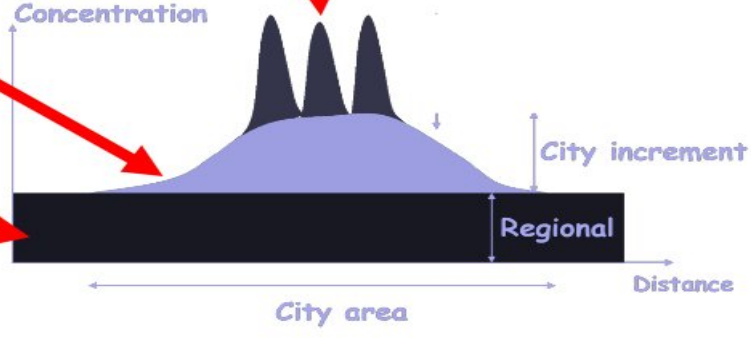








From amateur to professional science



Citizen Science

is scientific research conducted, in whole or in part, by amateur (or nonprofessional) scientists.

This may entail

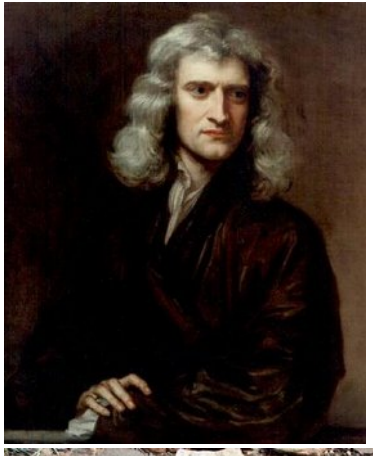
- collection of data
- interpretation/classification of data
- documentation
&
- bringing data into action

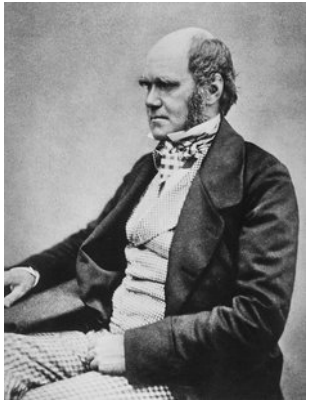
”Wisdom of the Crowd”

Citizen Science

A Long History

Science carried out by non-professional has always been a part of human culture -





DASYA

Air quality Index

Air Quality Index (AQI) typically based on

5 (+) indicator components:

Gases and particular matter

NO2, SO2, Ozone, PM2.5, PM10
+ CO, NH3, specific contributions

==> numerical index of overall AQ

Citizen Science in Air Quality

While we largely focus on

Sensor data

Citizen science entails **a lot more:**

- Human experience
  - Reflection
- Behavioural aspects
- Advocacy, policies, politics, action

Citizen Science in Air Quality

In recent interviews with CS projects, three areas of challenge:

- **“Hard” data – sensors, accuracy, ...**
- **People, individual**
- **Impact, social & political**

“Realising the triple objective of scientific rigour, policy influence and deep citizen engagement”

Van Brussel, S., & Huyse, H. (2019). Citizen science on speed? Realising the triple objective of scientific rigour, policy influence and deep citizen engagement in a large-scale citizen science project on ambient air quality in Antwerp. Journal of Environmental Planning and Management, 62(3), 534-551.

Air quality

Limits of classical science

Lab grade (“professional”) monitoring

limited to

- **small numbers of**
- **expensive monitoring stations**
- **not always representative**

Air pollution typically
local, hyperlocal – and highly dynamic
measure where the people are!

Air quality

Citizen science approach

measure where the people are,

with the people, for the people

Monitoring station

$$$$$

Un-usable by consumers
Reference for policy-making

Lab monitor

$$$

Complex to use for consumers
Reference for industrial applications

Consumer monitor

$

Easy to use for consumers
Reference for personal health

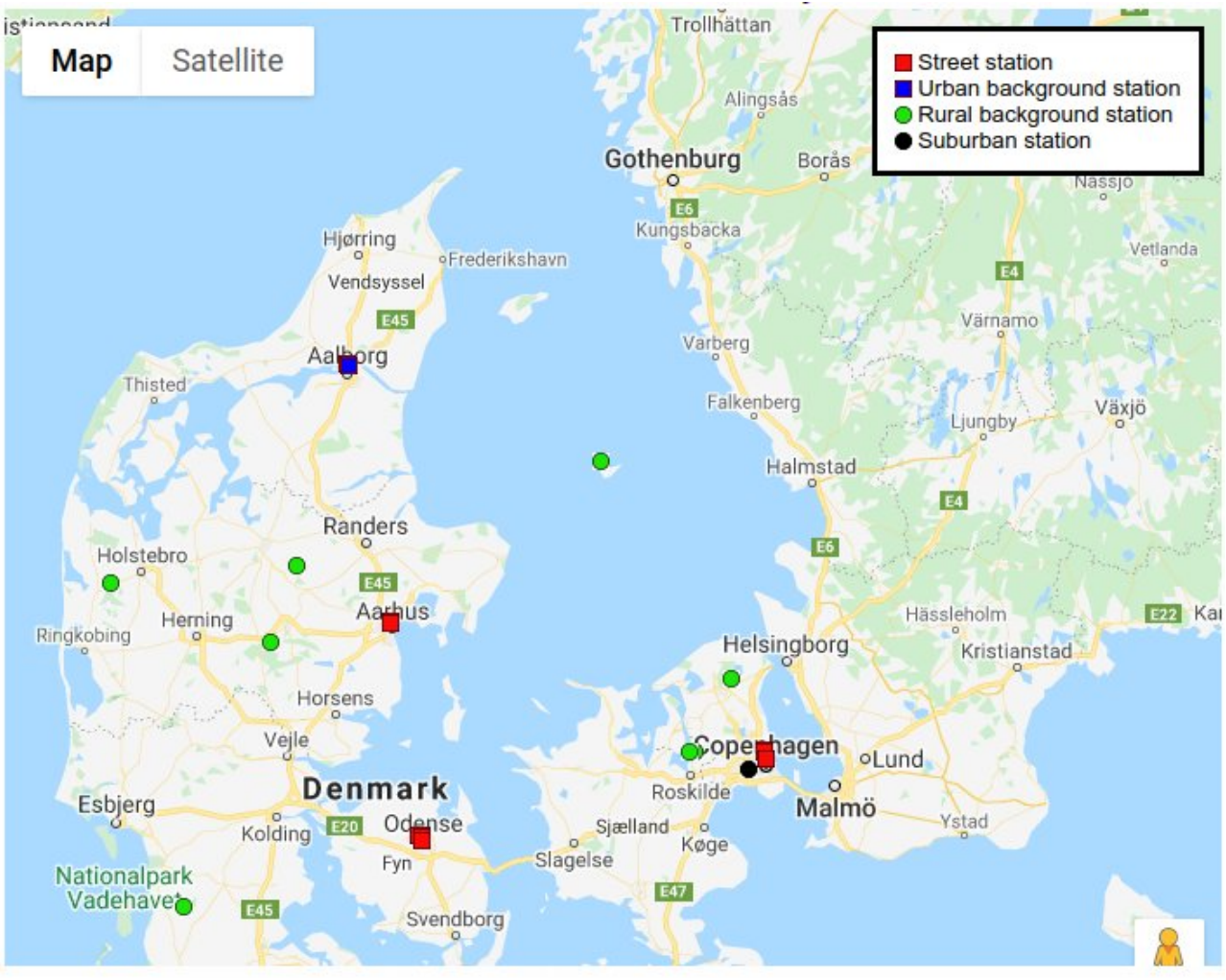
source: blogs.plumelabs.com

Copenhagen Monitoring Station

Air quality

Density of monitoring stations

… or lack thereof …

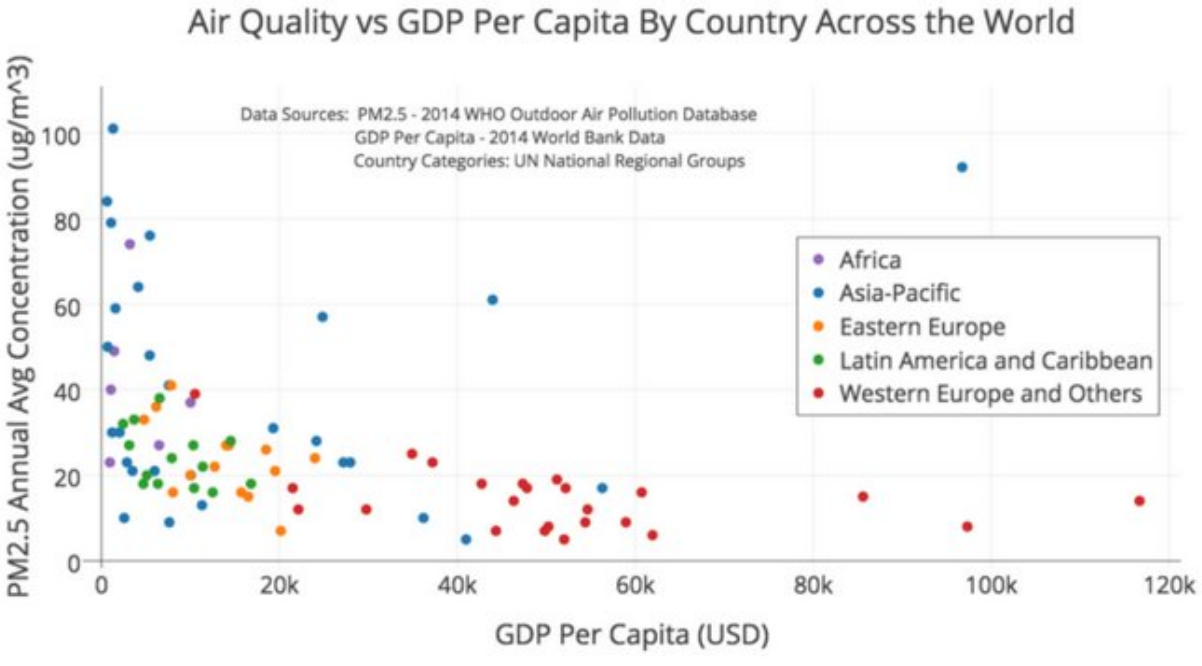


source: envs.au.dk

Air quality

Monitoring scales with GDP

OpenAQ – Global Air Inequality in two graphs

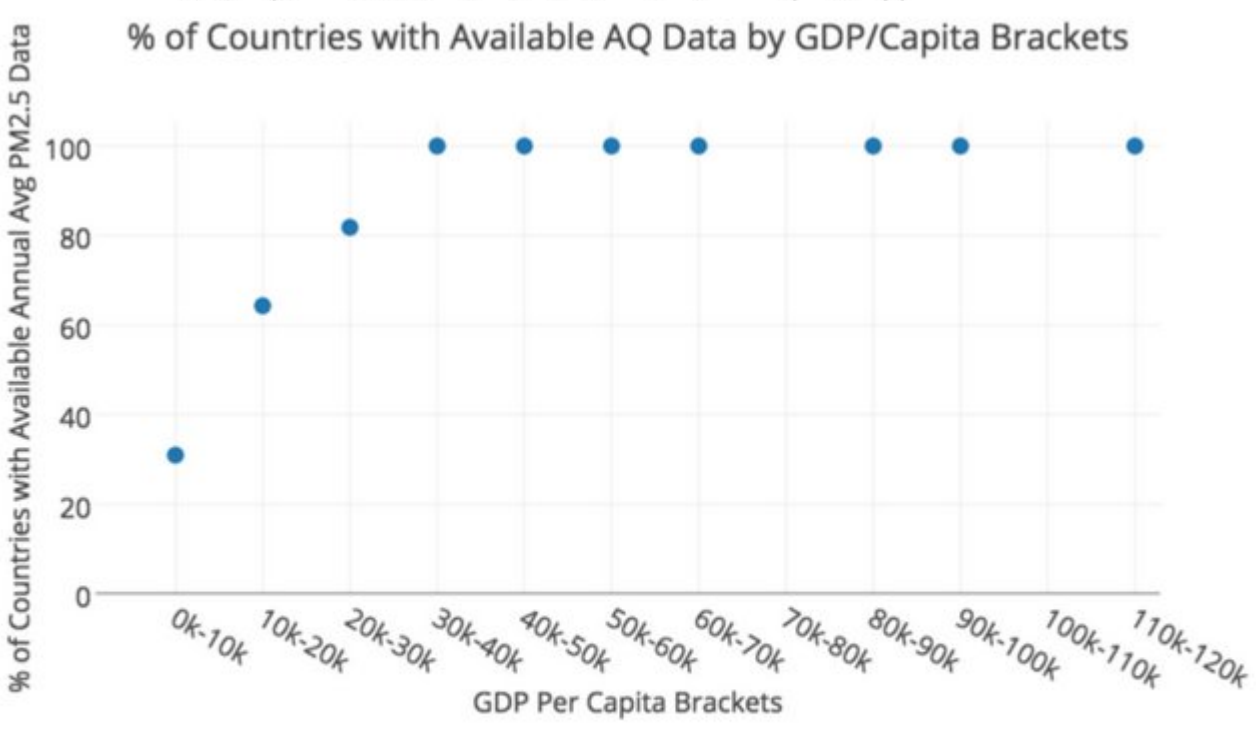


source: https://openaq.medium.com/global-air-inequality-summed-up-in-2-graphs-ad3d5a845033k

Air quality

Monitoring scales with GDP

OpenAQ – Global Air Inequality in two graphs

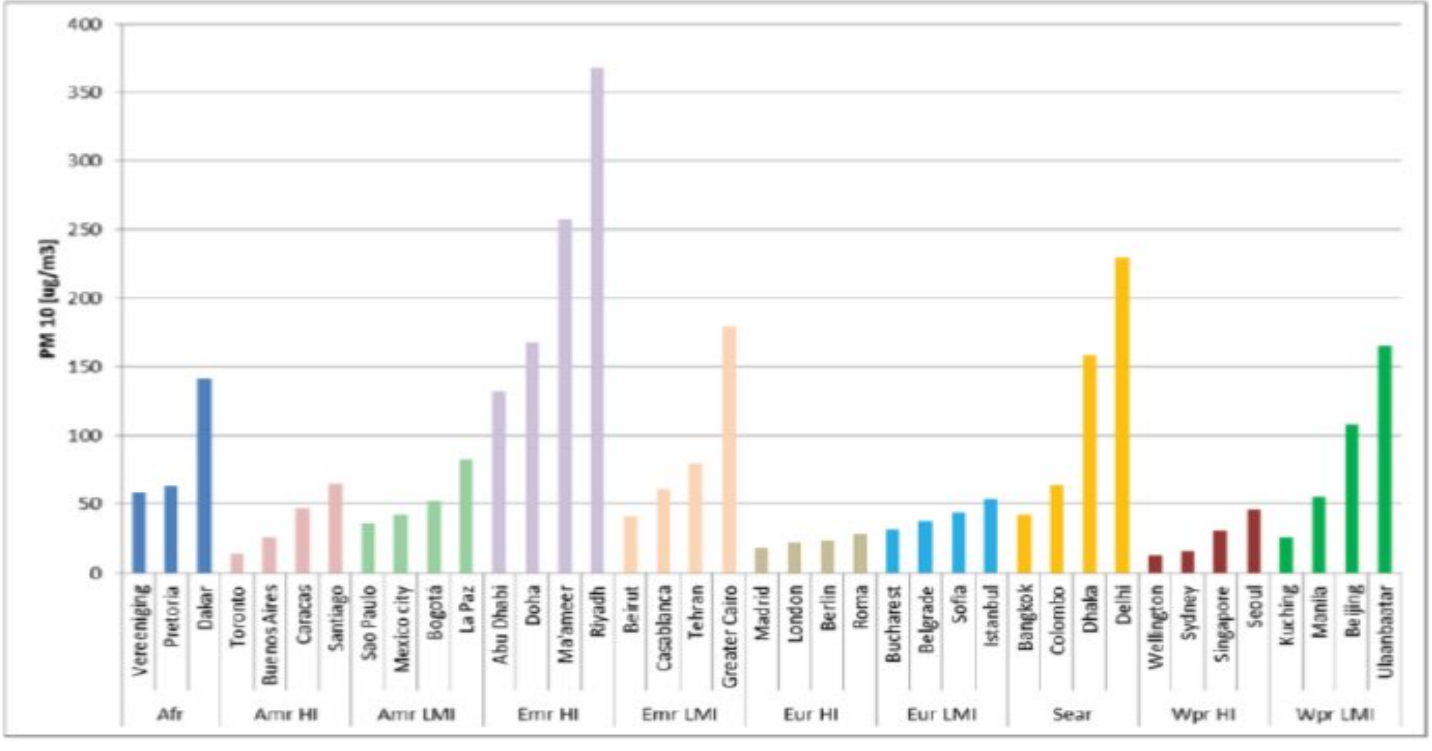


GDP per capita in USD. Sources: PM2.5 annual average concentrations are from 2014 WHO Air Pollution Database and the GDP per capita data is from 2014 World Bank data.

source: https://openaq.medium.com/global-air-inequality-summed-up-in-2-graphs-ad3d5a845033k

PM Inequality

Figure 3: *PM_{10} levels for selected[2] cities by region, for the last available year in the period 2011-2015.*



PM_{10}: Fine particulate matter of 10 microns or less; Afr: Africa; Amr: America; Emr: Eastern Mediterranean; Eur: Europe; Sear: South-East Asia; Wpr: Western Pacific; LMI: Low- and middle-income; HI: high-income.

http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

Air quality

The rise of citizen science

Growing interest in and acceptance of

citizen science contributions

Large funding programs, e.g. [Europe]
Science with and for Society (SwafS) in Horizon 2020

Fraisl, D., Campbell, J., See, L., Wehn, U., Wardlaw, J., Gold, M., & Fritz, S. (2020). Mapping citizen science contributions to the UN sustainable development goals. Sustainability Science, 15(6), 1735-1751.

A bit of a goldrush …

Over the last ~10 years,

an explosion of citizen science projects in air quality, with public as well as private sector programs

Not all of these citizen driven or living up to ethics of

open science

In a goldrush

… not all is gold.

When looking at citzen science.

check

data access & ownership?
science or greenwashing?
price & value?

?

source: https://glasgowcycleman.wordpress.com/2017/11/02/plumelabs-flow-air-quality-tracker-a-new-entry-to-the-green-consumption-market/

A word on open data …

“At Safecast.org, I pushed our team to use the CC0 public domain dedication for the data that we are collecting through our radiation measurements instead of a Creative Commons Attribution license, which would require by law that people give us attribution. The reason is that we must give people the flexibility to use the data as part of an analysis or service that would be encumbered or impossible with the attribution requirement.”

source: Safecast - https://joi.ito.com/weblog/2011/09/05/safecast-and-cc.html

An overview of projects …

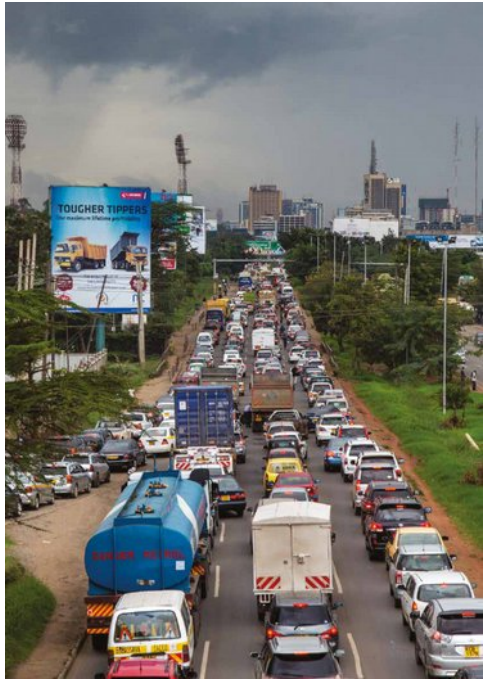
… is near-impossible …

Safecast https://safecast.org
Luftdaten/sensor.community https://sensor.community
Open Seneca https://open-seneca.org
Air Quality Egghttps://airqualityegg.com
Purpleair https://www.purpleair.com
Plumelabs https://plumelabs.com/en/
Smart Citizen Kit https://smartcitizen.me/
BreatheLondon https://www.breathelondon.org/
iQAir https://www.iqair.com/
CanAirIO https://canair.io/
URwatair https://eu-citizen.science/project/40
OpenAQ https://openaq.org
HabitatMap https://www.habitatmap.org/
PurpleAir https://www.purpleair.com
Carnegie Mellon University
TU Delft https://pubs.acs.org/doi/pdf/10.1021/acs.est.0c02436
CO2 ampel https://twitter.com/hashtag/CO2Ampel
PyonAIR southampton
https://www.seeedstudio.com/blog/2019/09/19/pyonair-team-up-to-tackle-air-pollution-with-iot/
AirCasting
MIT Senseable http://senseable.mit.edu/

source: Safecast - https://joi.ito.com/weblog/2011/09/05/safecast-and-cc.html

Projects:

e.g. Nairobi



UN-Habitat's Urban Pathway - Open Seneca
Collaboration between the University of Nairobi Science and Technology Park - Maker Space Lab, Open Seneca, the University of Cambridge and UN-Habitat.
https://unhabitat.org/citizen-scientists-measure-air-pollution-in-nairobi

Stockholm Environment Institute Africa (SEI), APHRC (African Population and Health Research Center), University of Nairobi, Slum Dwellers International Kenyan Chapter (popularly known as Muungano wa Wanavijiji), and the Horn of Africa Regional Centre and Network (HOAREC) in Ethiopia have teamed up to use the citizen science approach
https://council.science/current/blog/citizen-science-for-improved-air-quality-in-nairobi-and-addis-ababa/

MIT sennselabs - CLEAN AIR NAIROBI
http://senseable.mit.edu/cleanair-nairobi/
http://senseable.mit.edu/papers/pdf/20171215_deSouza-etal_NairobiExperiment_CleanAir.pdf
Alphasense Sensors

SEI – various projects 2012-now, AQD-Nairobi
https://www.sciencedirect.com/science/article/pii/S0143622818307938
West, S. E., Büker, P., Ashmore, M., Njoroge, G., Welden, N., Muhoza, C., ... & Apondo, W. (2020). Particulate matter pollution in an informal settlement in Nairobi: Using citizen science to make the invisible visible. Applied Geography, 114, 102133.

London Sustainability Echange - FIA Foundation
https://www.fiafoundation.org/media/461309/cleaner-air-4-schools-print.pdf

sensors.AFRICA Air Quality Archive Nairobi
https://africaopendata.org/dataset/sensorsafrica-airquality-archive-nairobi

2018
Liquid Telecom's network will help CfA expand its network of citizen science sensors
https://medium.com/code-for-africa/cfa-partners-with-fibre-network-to-map-deadly-air-pollution-5e95d102a095

source: Safecast.org

Projects: Safecast

Founded 2011,
after the Fukushima incident

an international volunteer driven non-profit organization

initially focusing on radiation

but quickly extending into

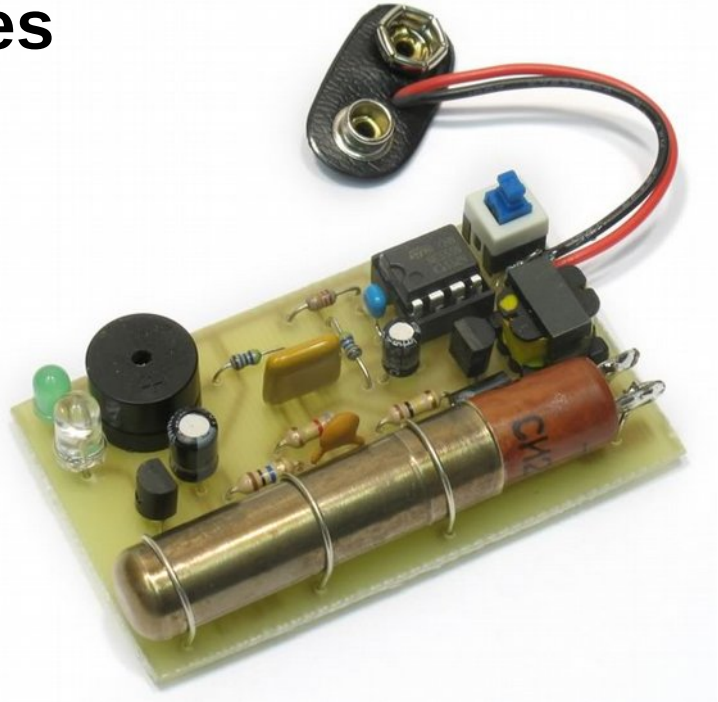
air pollution monitoring

source: Safecast.org

Projects: Safecast

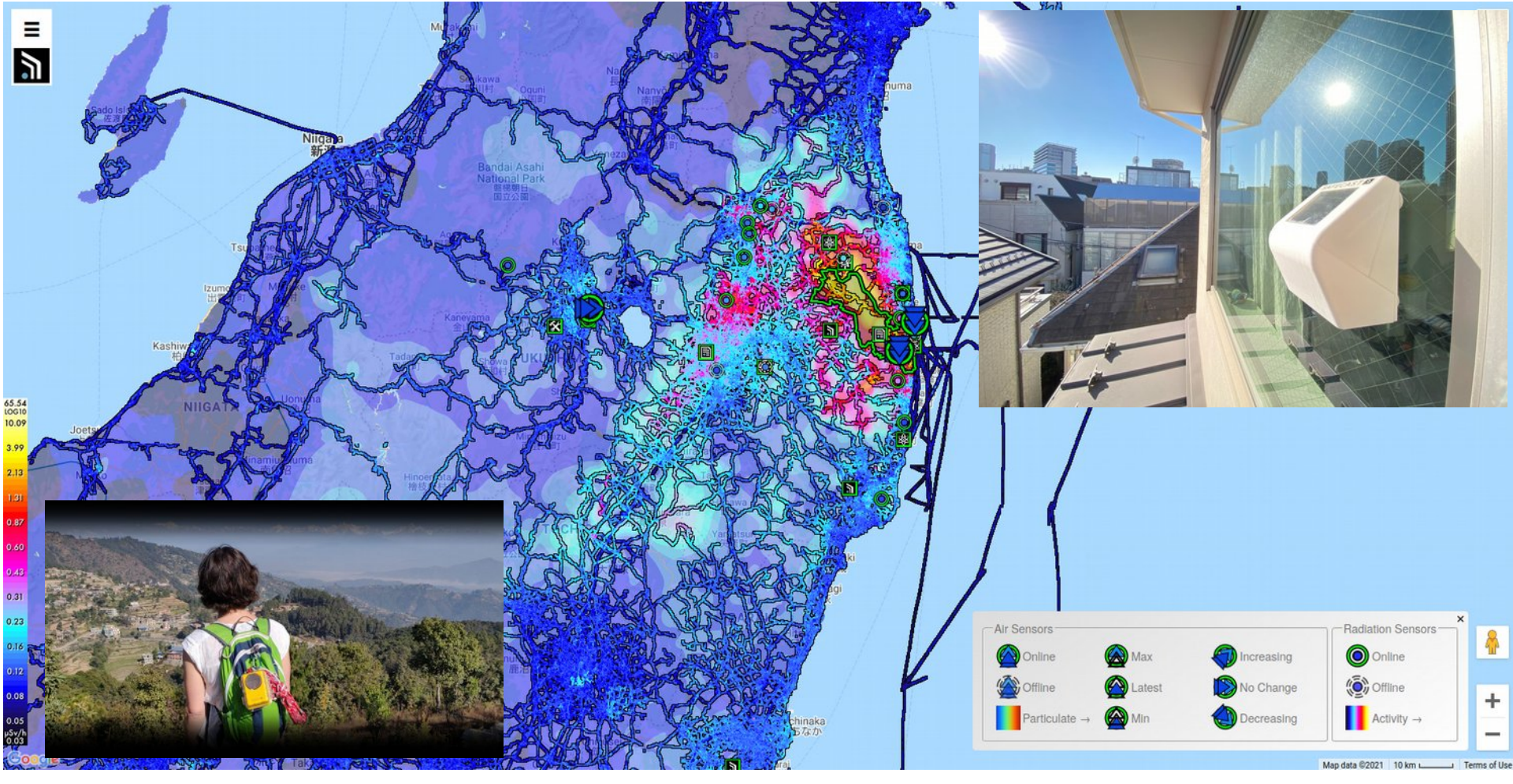
Early prototypes

2012 (?)



source: Safecast.org

Projects: Safecast



IT UNIVERSITY OF COPENHAGEN

source: Safecast.org

Projects: Luftdaten

sensor.community

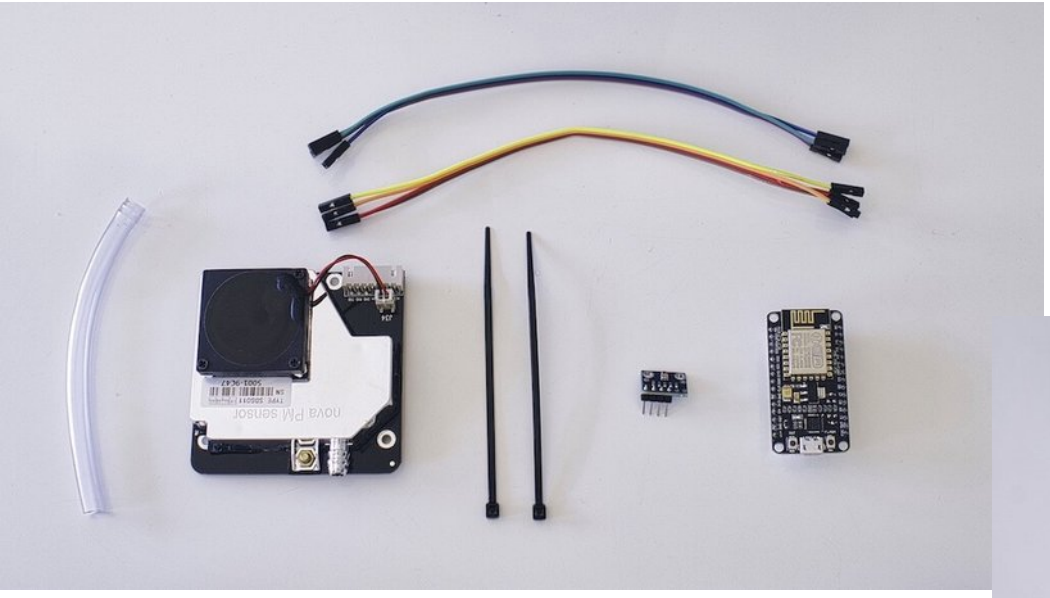
“Sensor.Community is a contributors driven global sensor network that creates Open Environmental Data.

Our mission is to inspire and enrich people’s lives by offering a platform for the collective curiosity in nature that is genuine, joyful and positive.”

Started at OK Lab Stuttgart

source: sensor.community

Projects: Luftdaten / sensor.community



sensor: SDS011
board: NodeMCU

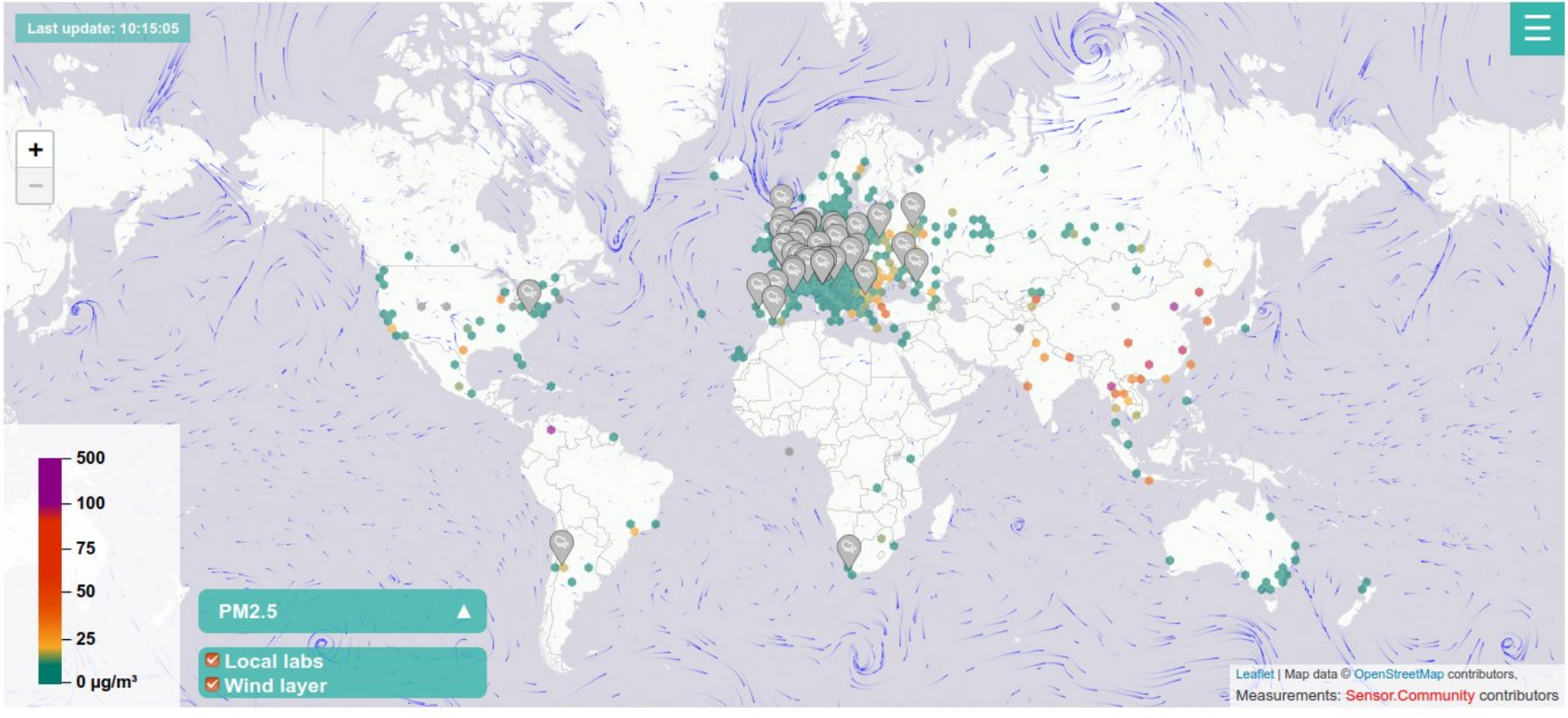
“AirRohr” = the Air tube

source: sensor.community

Projects: Luftdaten / sensor.community

source: sensor.commuity

Projects: Luftdaten / sensor.community

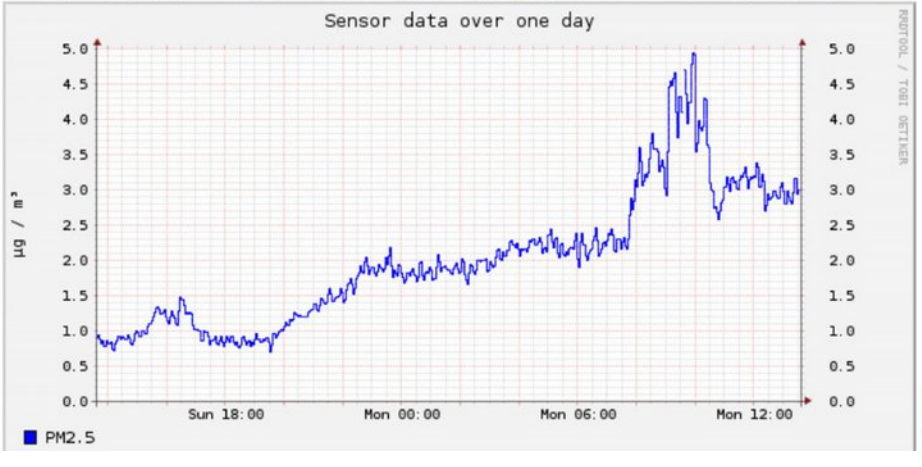


source: sensor.commuity

Luftdaten

at DASYALab

10 Sept 2019



Projects: Open Seneca

Mobile, bicycle based

source: open-seneca.org

Projects: Open Seneca

Mobile, bicycle based

Cambridge: the first proof-of-concept sensor network driven citizen science with 20 sensors mounted on cycling volunteers (summer 2018). The results confirmed the feasibility of using low-cost sensors to produce air quality maps showing hotspots of air pollution and highlighted the raise in awareness in the community. Currently, the main focus of open-seneca activities in Cambridge is educational, running workshops in primary schools and outreach events.

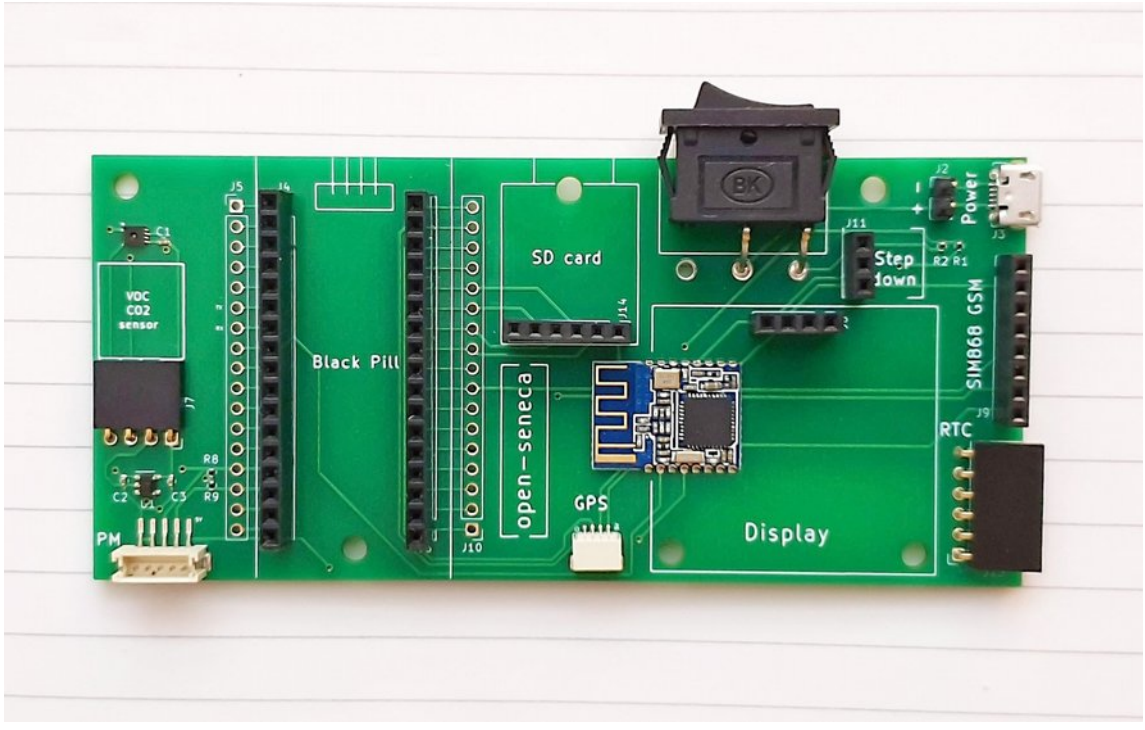
Testing our first air quality sensor!

source: open-seneca.org

Projects: Open Seneca

open source designs & software

volunteer-driven



source: open-seneca.org

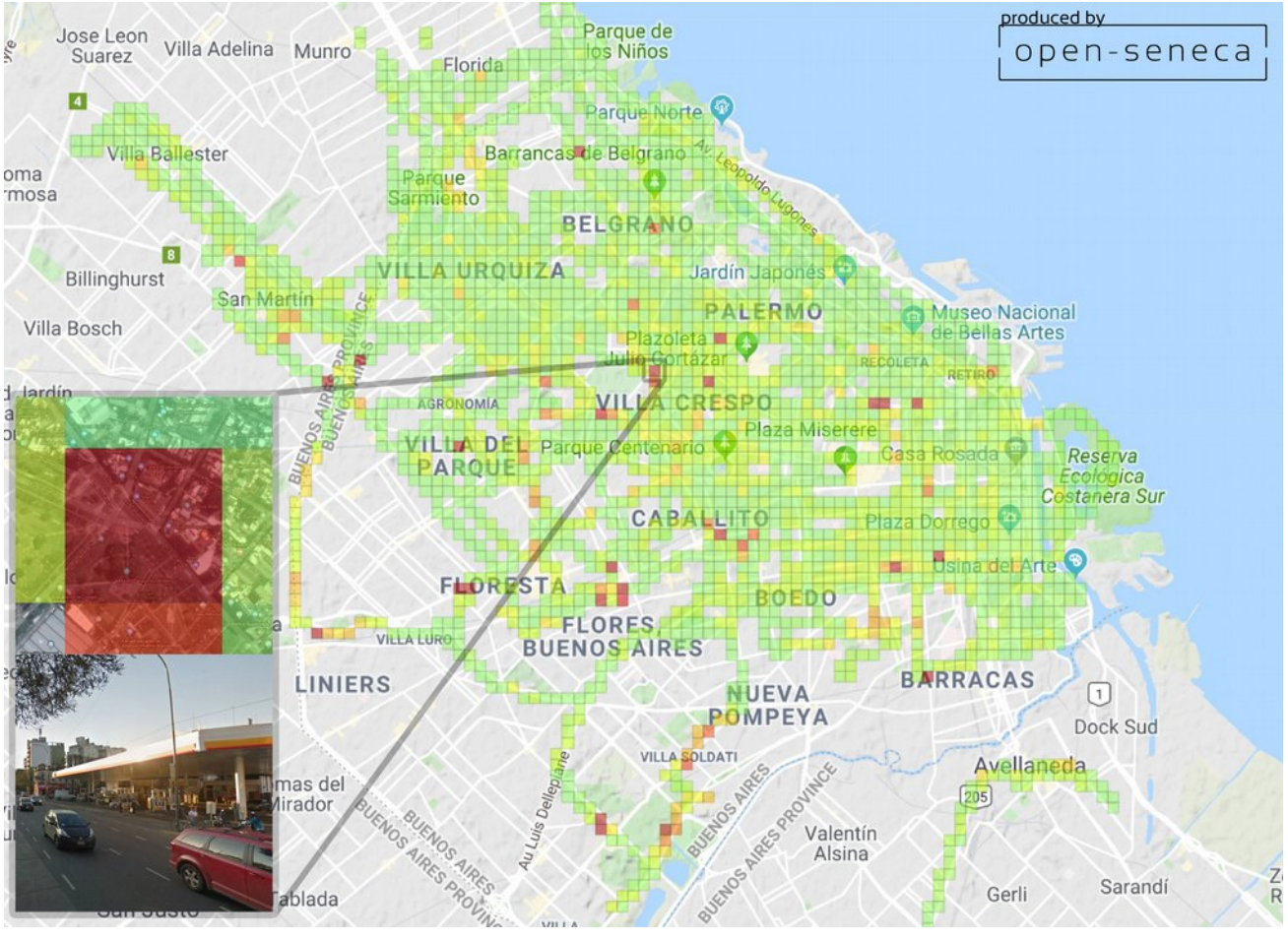
Projects:
Open Seneca

Buenos Aires

Nairobi

Lisboa

Stockholm



source: open-seneca.org

Outdoor

&

Indoor

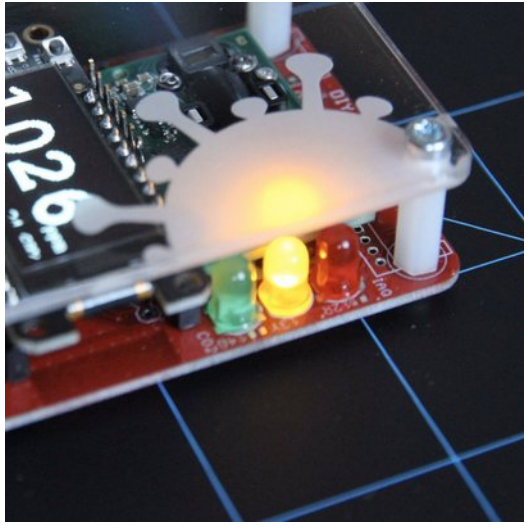
.. are distinct, with regards to which pollutants are of interest:

for indoors monitoring:

CO2
VOC (volatile organic compounds)
PM (particulate matter)

CO2 acting as indicator for “fresh air” or lack thereof → **importance in times of the covid pandemic!**

Projects: CO2Ampel



An informal movement rather than a well-defined project.
originated
Umweltcampus Birkenfeld, Germany

Largely grouped around a twitter hashtag,
#CO2Ampel

driven by
Guido Burger et al.

Projects: CO2Ampel

Dozens to hundreds of designs, guides, hardware versions

Schools as primary target (challenge: data exchange/access!)

Maker magazine MAKE giving away free PCBs

Sensor: Sensirion (which became bottleneck ...)

(Bild: Guido Burger)

source: @guido_burger on twittter

DASYA

Projects: CO2Ampel

Die #CO2Ampel läuft und wird genau beobachten was am Montag passiert ... wir dokumentieren! #CitizenScience wenn der Staat versagt …

#CO2Lights running … observing what will happen on monday (this monday!)

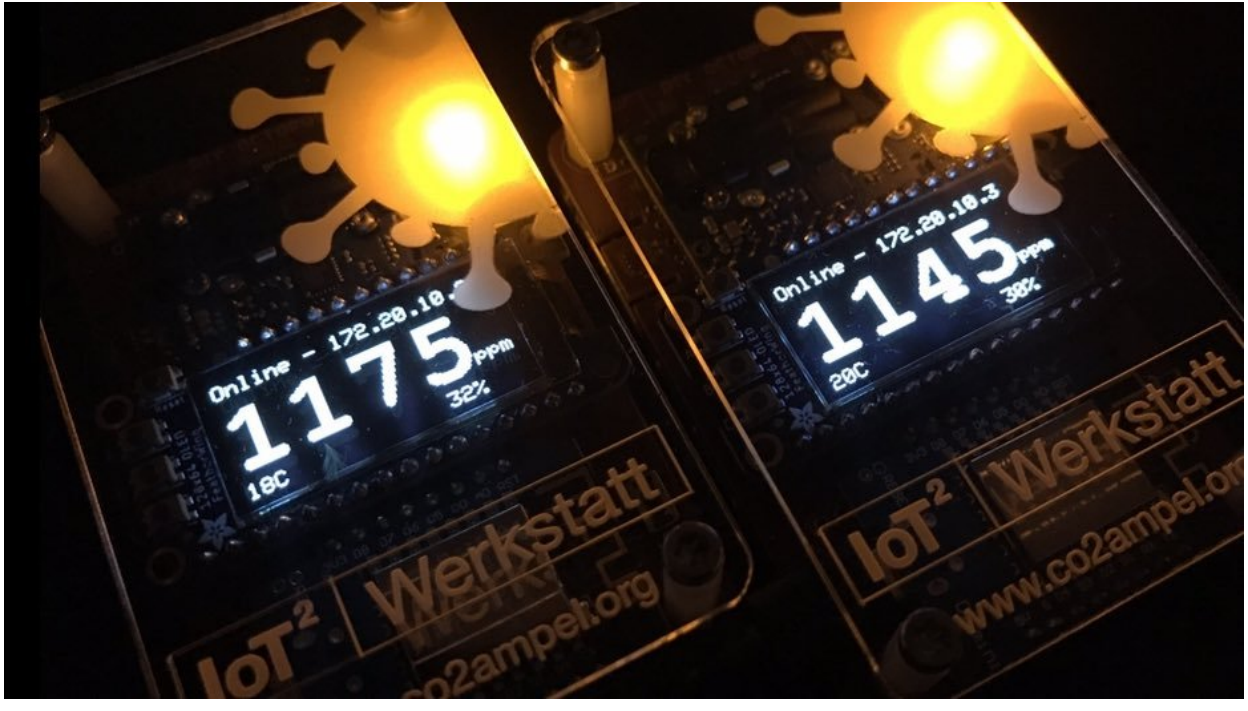
CitizenScience when your government fails you ...

source: @guido_burger on twittter

Projects: CO2Ampel

Monitoring policies, behaviour

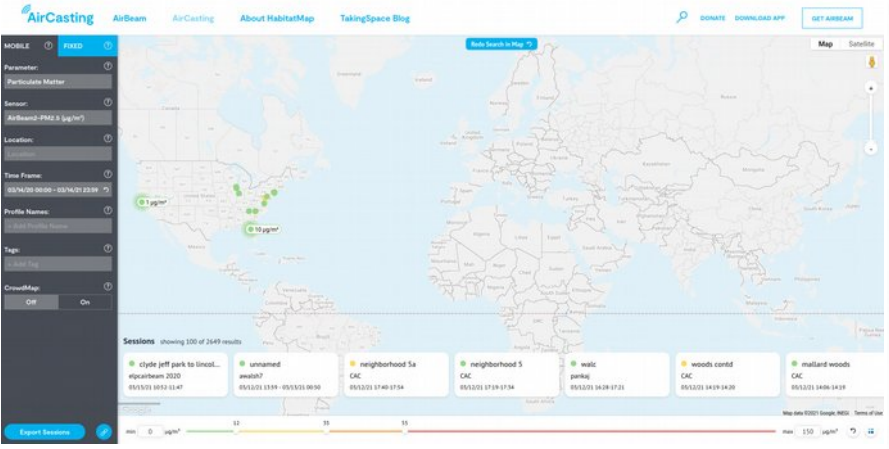
15 March, 2021
Re-opening of schools in Germany

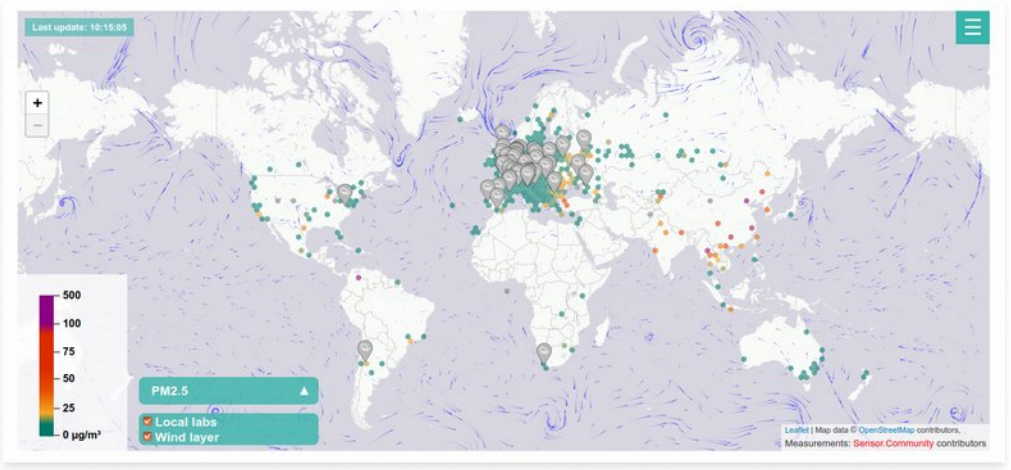


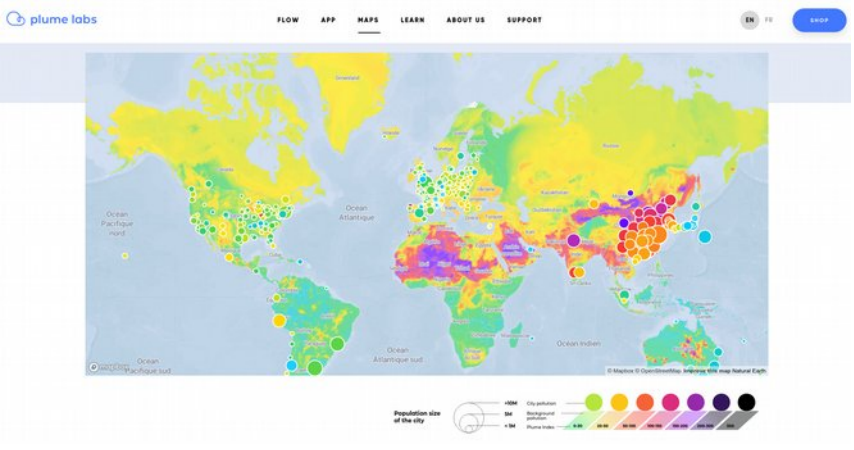
Projects: CO2Ampel at my desk

source: Sebastian's desk

Status – where are we, globally?







Main challenges

Accuracy

Continuity

Impact

Sensors, quality, accuracy

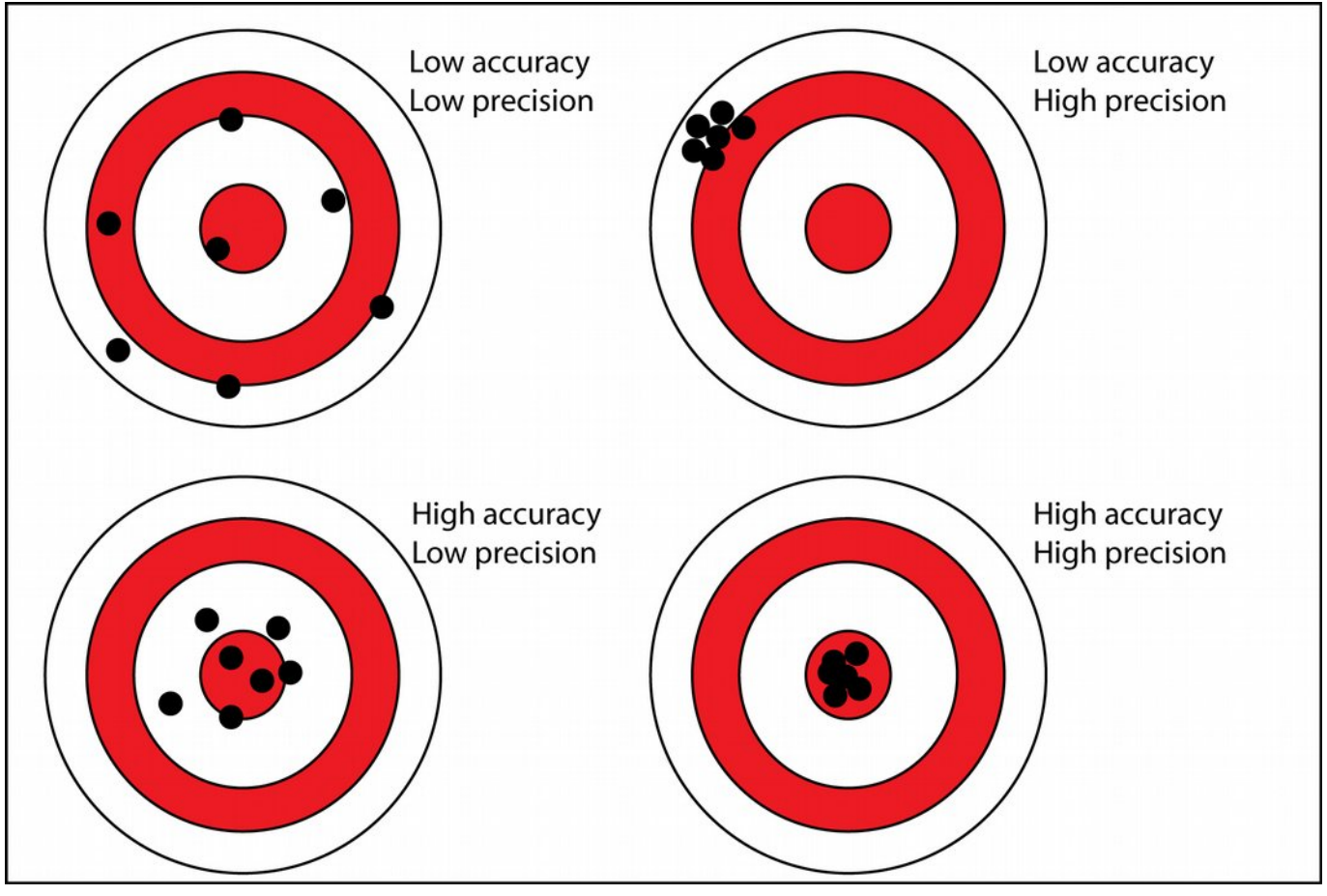
With low-cost sensors, accuracy is an issue.

However, consider the requirements:
The EPA Air sensors guideline1 classifies the performance of air quality sensors in five types (Tiers I-V). The suggested performance goals are summarised in the table below

Tier	Application area	Uncertainty
I	Education and information	±50%
II	Hotspot identification and characterisation	±30%
III	Supplemental monitoring	±20%
IV	Personal exposure	±30%
V	Regulatory monitoring	±10%

source: open-seneca.org
https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook

Sensors / Terminology III / Accuracy & Precision



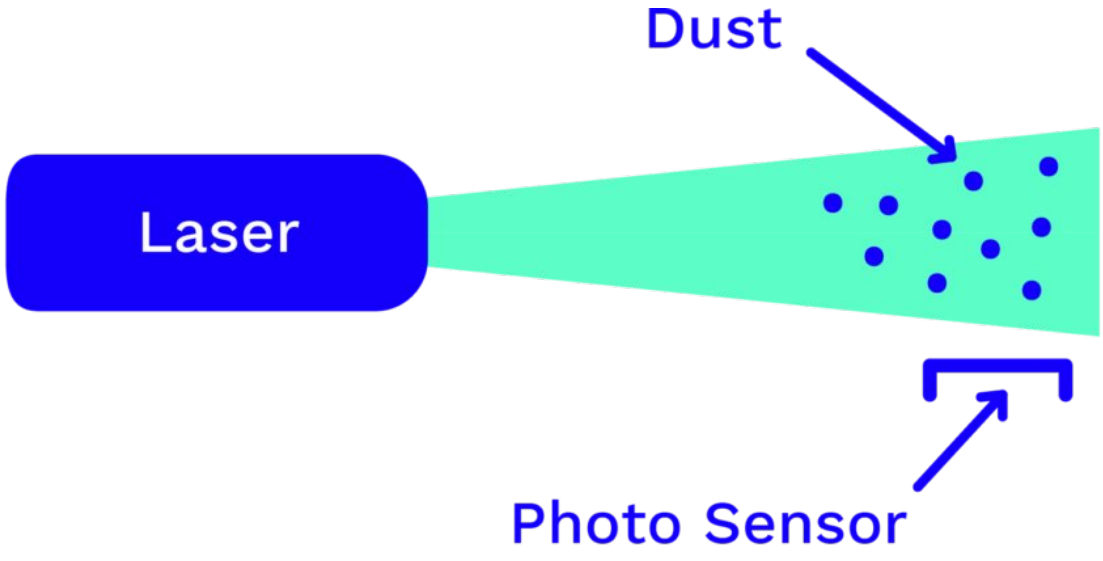
Sensors / Terminology I

- Sensitivity – minimum change needed to change output
- Range – minimal and maximal values
- Precision – spread/variation
- Resolution – about minimal difference that can be told apart
- Accuracy – bias, closeness to accepted “true” value
- Offset
- Linearity
- Hysteresis
- Drift
- Response Time
- Rate

http://www.ni.com/white-paper/14860/en/

Sensors, quality, accuracy

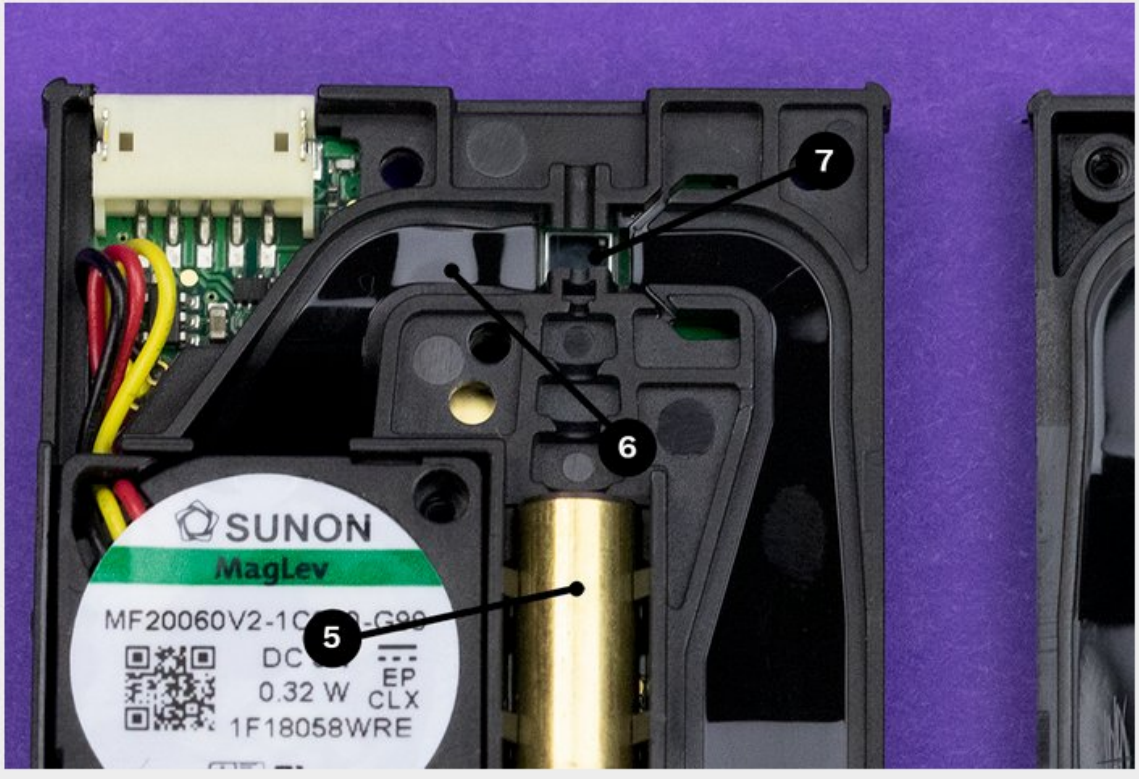
For particulate matter, low-cost sensors typically are optical sensors.



source: https://www.mistywest.com/posts/teardown-sensirion-particle-matter-sensor/

Sensors:

Sensirion SPS030 inside



We can see these features in the Sensor. The laser (*Part 5*), the airflow path (*Part 6*), and the photosensor (*Part 7*).

source: https://www.mistywest.com/posts/teardown-sensirion-particle-matter-sensor/

Sensors / Air VI / PM

- Particulate Matter (PM) comes from many sources, and in many places is among the biggest environmental health hazards (car traffic, stoves, fires, road dust, ..)

source: GFDL, https://en.wikipedia.org/w/index.php?curid=48987967

Sensors / DASYALab & AU – NO2, PM

- Collaboration with Department of Environmental Science, AU - NO2 series, calibration, networks, Alphasense sensors

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PIT LAB
PERVASIVE INTERACTION TECHNOLOGY LABORATORY

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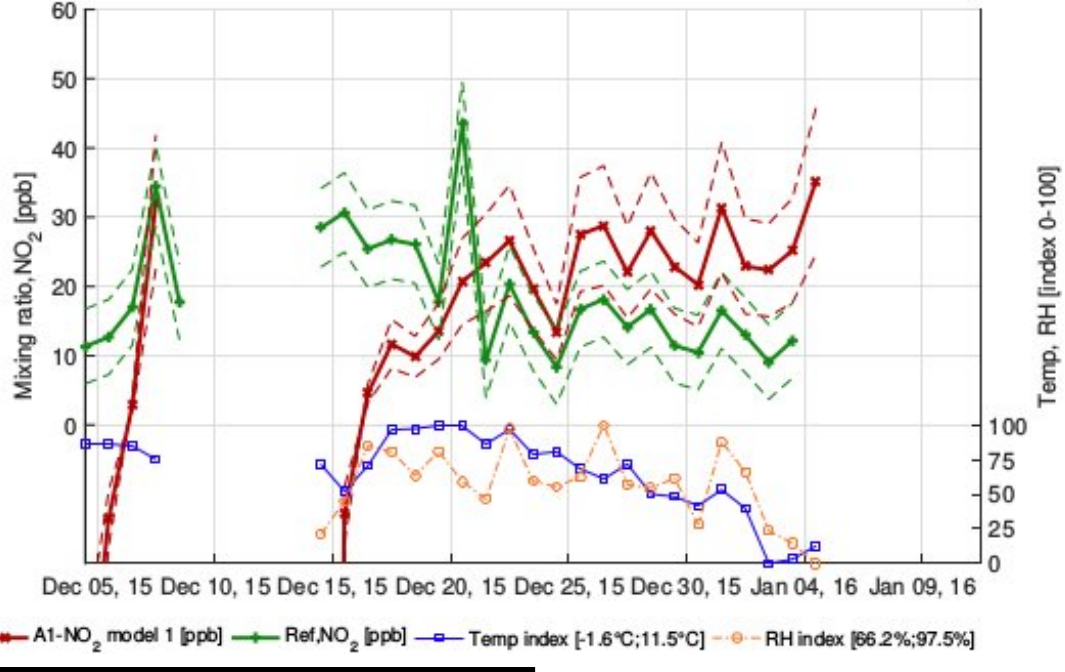

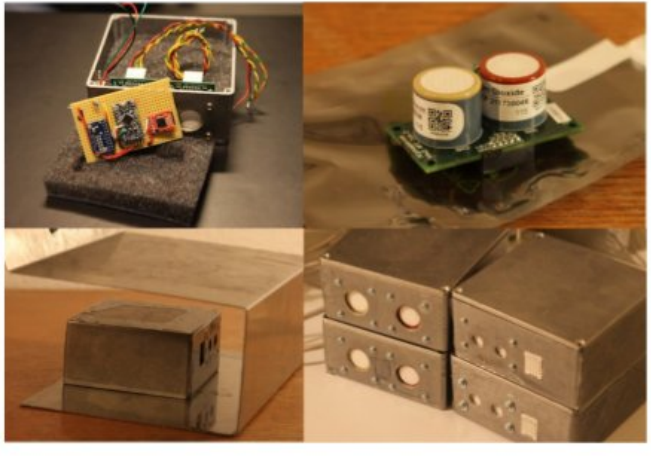

Assessing the applicability of low-cost electrochemical gas sensors for urban air quality monitoring

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Sensors:

The most common low-cost PM sensors

Nova SDS011

Sensirion SPS30, SCD40/41

Plantower PMS7003

Alphasense OPC-N2

Shinyei

Sharp

Dyson DC1100 as reference

+ many more …

Sensors:

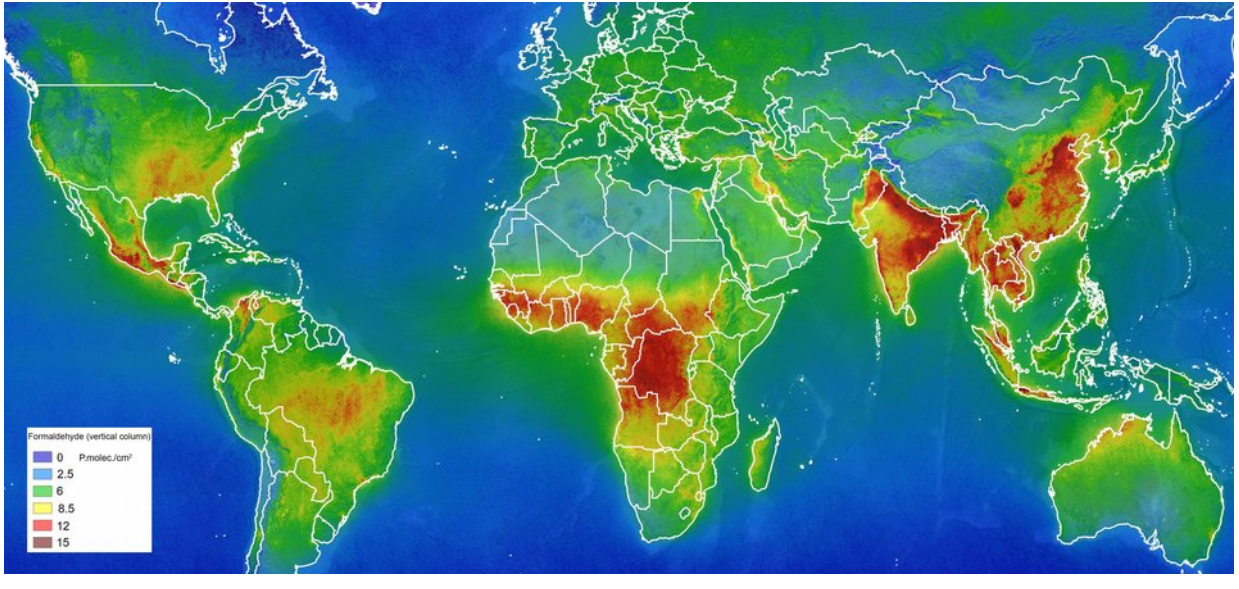
New trends

Machine Learning, “Artificial Intelligence”?

Eirini Malliaraki @irinimalliaraki · Mar 13

Wait...has ML, cheaper sensors and big computers brought citizen science to an end??

Satellites, remote sensing



source: 5p sentinel

Continuity

Continuity of engagement

Citizen science projects often face challenge of keeping volunteers engaged,
often have short lifetimes

Motivations?

Is gamification a strategy?

Impact

Translation into action, policy, change
What are the mechanisms?

How many obvious pollutors have been shut down or reglemented because of CS data?

November 25, 2019

Harder To Breathe: Air Quality has Worsened Since 2016

A CMU study finds recent increase in fine particulate matter are associated with more premature deaths in U.S

By Noelle Wiker

› Media Inquiries

In the United States, annual average levels of fine particulate matter — PM2.5, a measure of solid particles and liquid droplets that are 2.5 micrometers or smaller found in the air — declined 24% from 2009 to 2016, then increased 5% between 2016 to 2018.

source: Clay, K., Muller, N. Z., & Wang, X. (2021). Recent increases in air pollution: evidence and implications for mortality. Review of Environmental Economics and Policy, 15(1), 000-000.

Impact

‘In the future we may well have scientists at work everywhere, producing facts with the speed that new sophisticated instruments make possible, but the way those facts will be interpreted will mostly confirm the landscape of settled interest.’ –

Isabelle Stengers, A Plea for Slow Science, 2011

Or can we change that?

source: Stengers, I. (2016). “Another Science Is Possible!”: A Plea for Slow Science. In Demo (s) (pp. 53-70). Brill Sense.

Impact

Research article

Citizen science on speed? Realising the triple objective of scientific rigour, policy influence and deep citizen engagement in a large-scale citizen science project on ambient air quality in Antwerp

Suzanne Van Brussel & Huib Huyse

Pages 534-551 | Received 22 Mar 2017, Accepted 08 Jan 2018, Published online: 13 Feb 2018

Download citation https://doi.org/10.1080/09640568.2018.1428183 Check for updates

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Abstract

Citizen science projects are increasingly recognised as catalyst for triggering behaviour change and building social capital around environmental issues. However, overview studies observe recurrent challenges in many citizen science projects in terms of combining high levels of data quality with deep citizen engagement and policy influence. This paper reports on the findings of the CurieuzeNeuzen project (www.CurieuzeNeuzen.eu), a large-scale citizen science project on air quality in Antwerp, delivering results in the three areas described above. Through CurieuzeNeuzen, 2,000 citizens studied the air quality levels in and around Antwerp in 2016 and were intensively deliberating on possible causes and solutions. Surveys were conducted at the start and towards the end of the project, with participants stating that their participation resulted in changed views and behaviour towards air pollution, mobility solutions, and city planning. The findings were picked-up academically and contributed to policy debates on air quality at city and regional level.

Keywords: Citizen science | air quality | environmental democracy | behavioural change | Antwerp

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Thank you!

Accuracy?

Continuity?

Impact?

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DASYA