An Intelligent Air Quality Monitoring and Prediction System for Smart Cities

Sustainable HEP – 2nd addition

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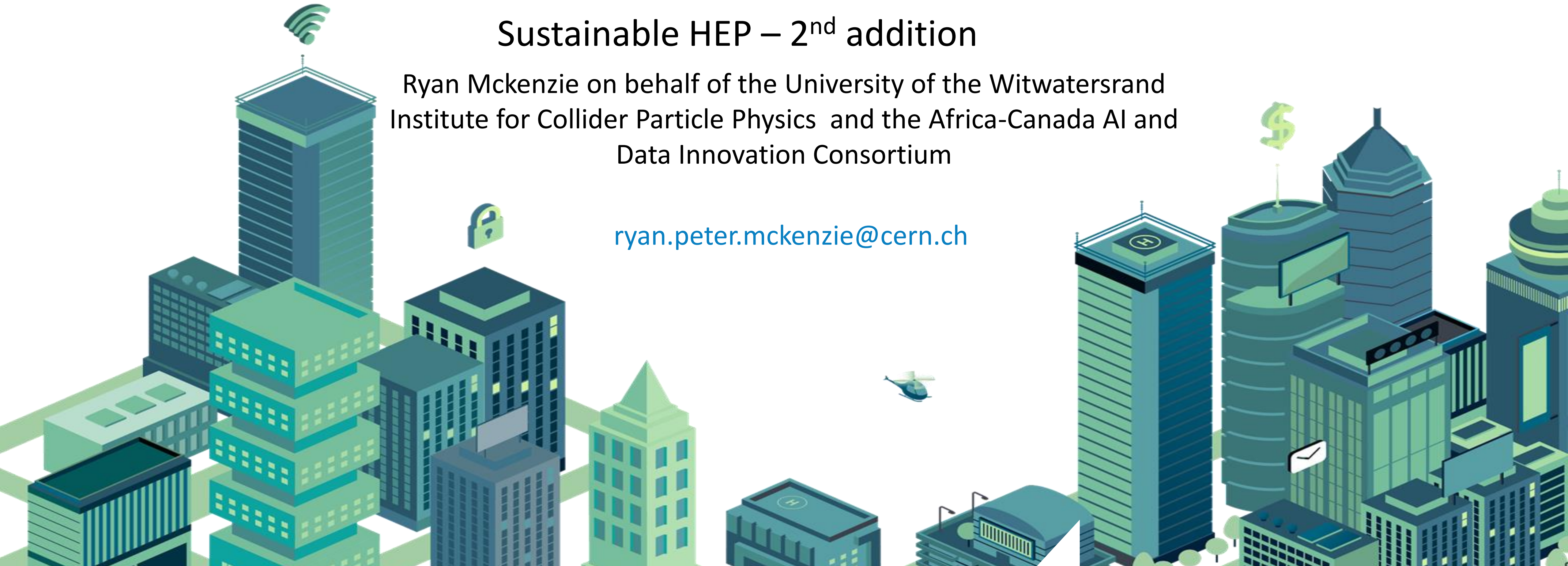


South Africa at CERN

- The Tile-Calorimeter (TileCal) is a sampling calorimeter which forms the central region of the Hadronic calorimeter of the ATLAS experiment.
- A Low-Voltage Power Supply (LVPS), of which there is one per TileCal module, steps down 200 V DC, received from off-detector high-voltage supplies, to the 10 V DC required by the front-end electronics.
- All LVPSs will be replaced as part of the ATLAS Phase-II upgrade.
- South Africa is manufacturing, and testing half of all phase-II upgrade

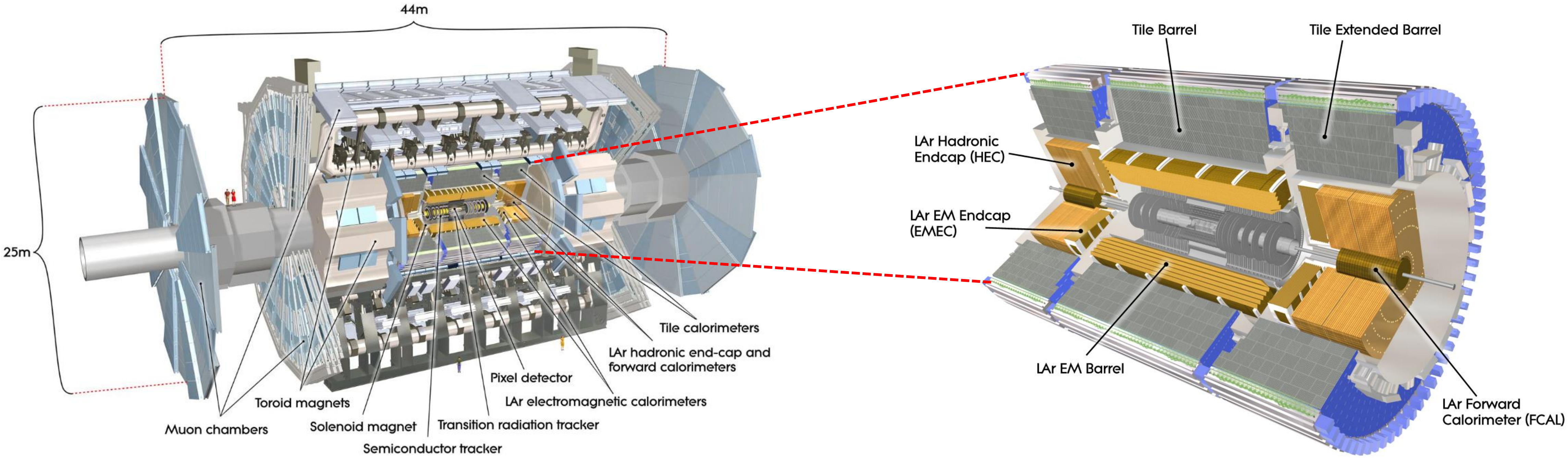


Fig. The ATLAS detector (Left). The ATLAS inner Barrel (Right) -*J. Pequenao, Computer Generated image of the ATLAS calorimeter,(2008), https: // cds. cern. ch/ record/ 1095927*

Tech Transfer for Good

Objective 1

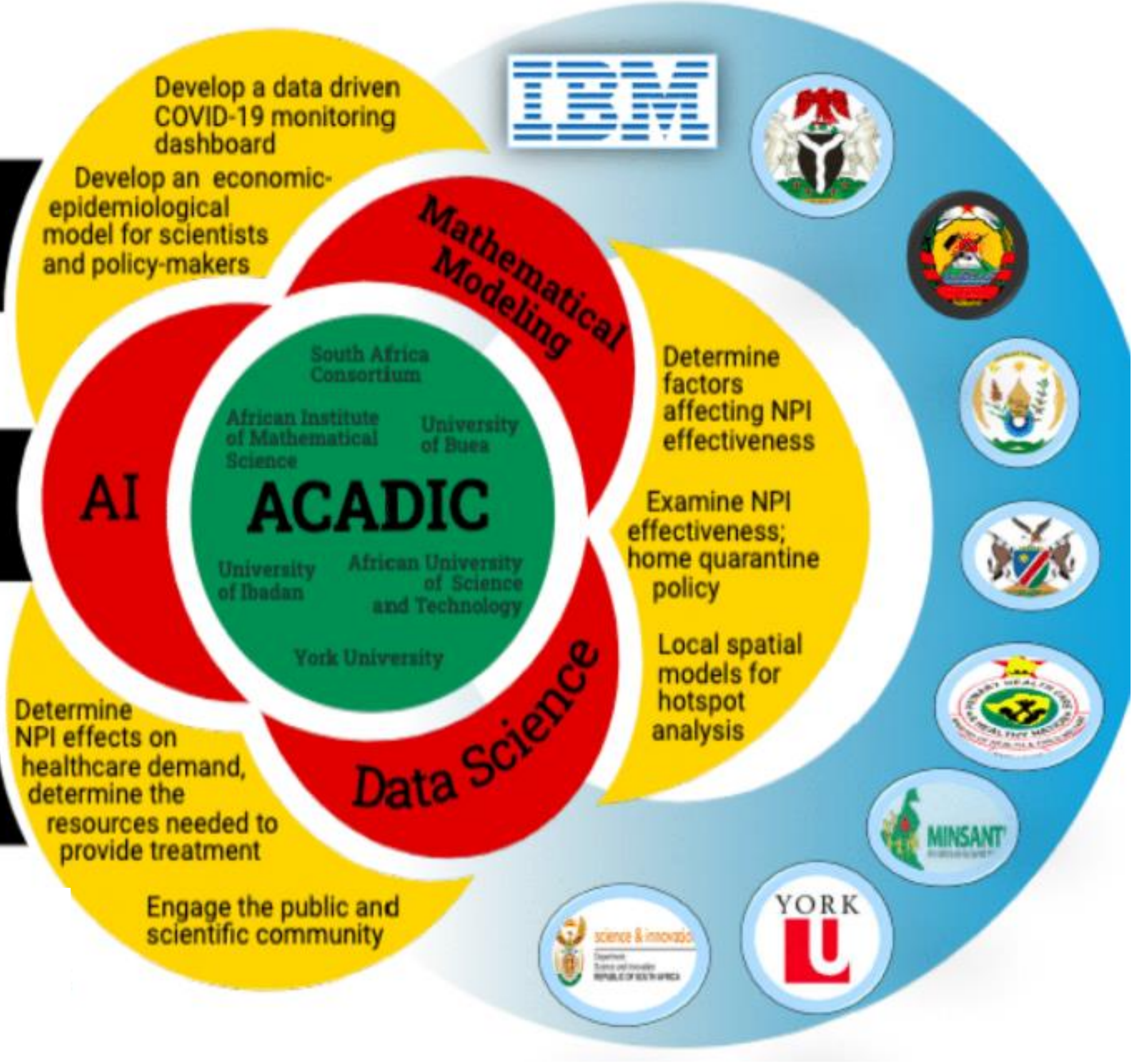
Aid policy makers in mitigating/surpressing outbreaks

Objective 2

Evaluate relative effectiveness and potential biases of PHIs

Objective 3

Support local communication strategies to address mis-information about prevention and treatment.



Why Air Quality Matters

- It is an effective probe into a broad range of public health issues.
- It is important to manage public health responses and governance.
- Poor air quality is known to be linked to chronic conditions and other health-related issues.
- Reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma.

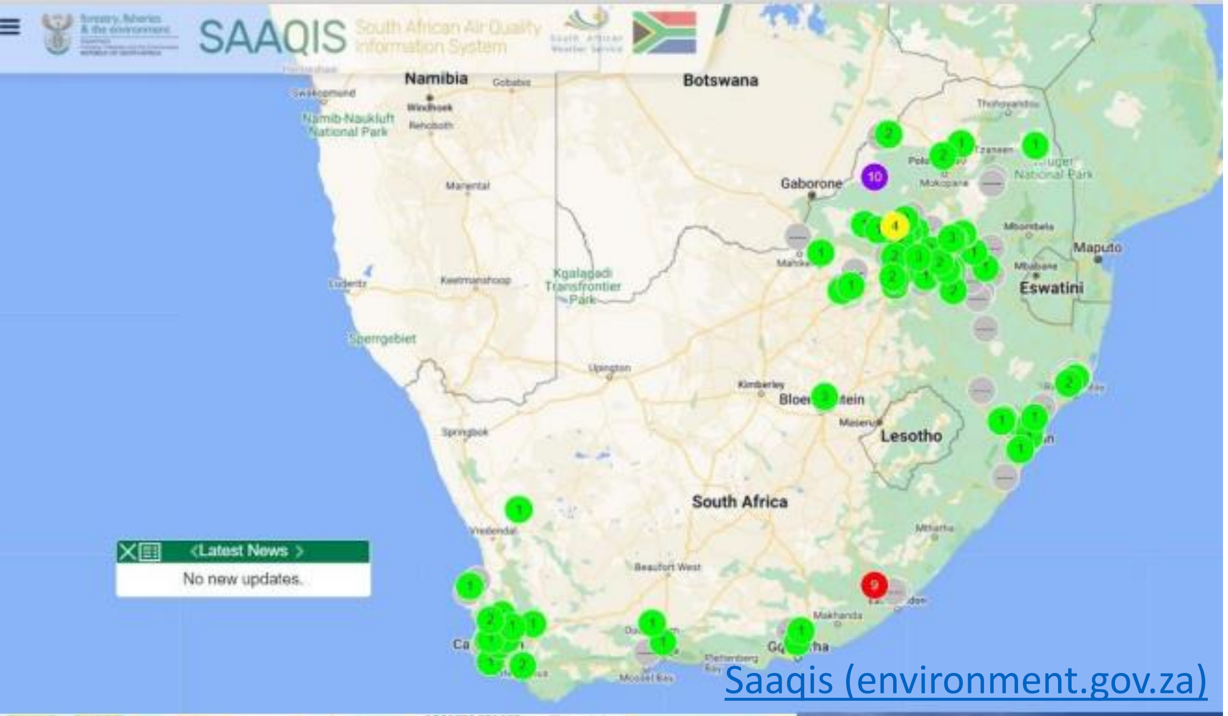
7 Million people die from air polution anually

This includes more than 1.7 million child deaths a year worldwide.

2.4 Billion people cook and heat their homes with biomass, kearosean and coal.

In 2019 99% of people were found to breath air that exceeds WHO air quality limits

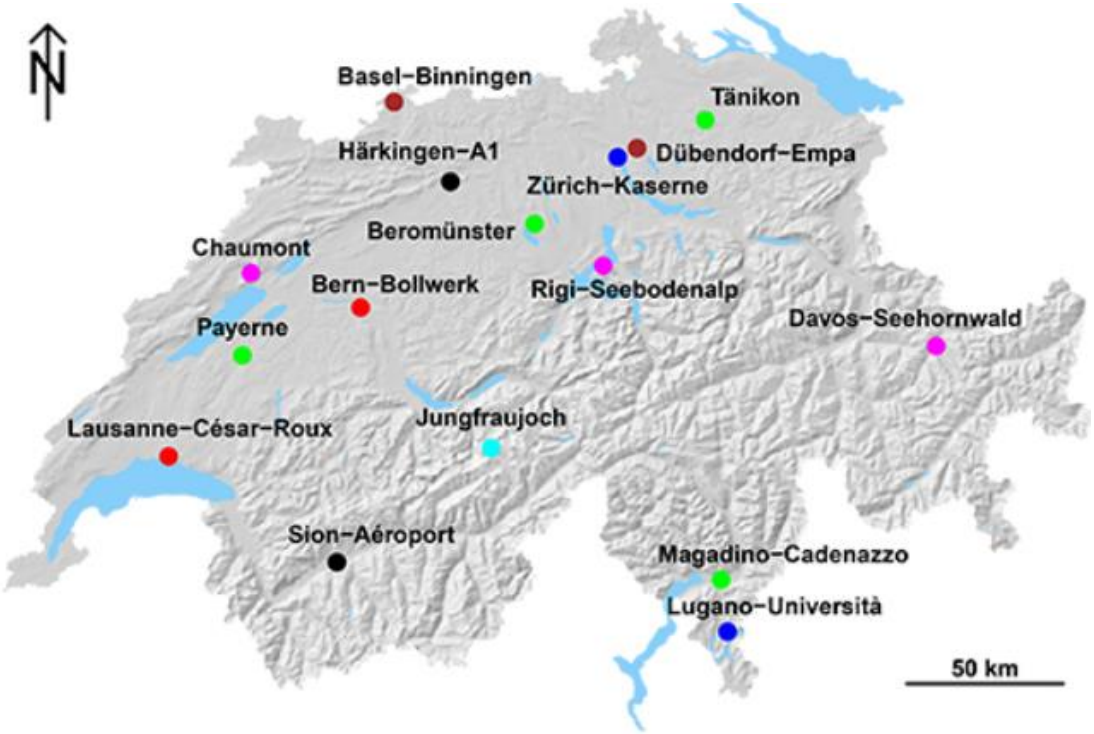
Ambient (outdoor) air pollution (who.int)



Saaqis (environment.gov.za)

Shortcomings in current air quality monitoring systems

Due to the high cost and complexity associated with the deployment of a traditional air quality monitoring stations countries are forced to allocate their limited resources to monitor certain 'priority' sites which necessitates the omission of others. <u>This problem is one faced by many countries.</u>



The South African Consortium of Air Quality Monitoring

The International consortium was founded with the goal of bringing together government institutions, research institutions, and private enterprises into a mutually beneficial ecosystem in order to deliver a low-cost intelligent IoT air quality monitoring system.

Perovskia

Africa | Canada Artificial Intelligence and Data Innovation Consortium

forestry, fisheries & the environment
Department: Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

science & technology
Department: Science and Technology
REPUBLIC OF SOUTH AFRICA

IDRC · CRDI
Canada

DAHDALEH INSTITUTE FOR GLOBAL HEALTH RESEARCH

CERN

WITS UNIVERSITY

NORDIC SEMICONDUCTOR

healthmetryx

Sida

YORK UNIVERSITÉ UNIVERSITY

UNIVERSITY OF ZULULAND

VNIVERSITAT DE VALÈNCIA

SAAQIS
South African Air Quality Information System

GAUTENG
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

NRF National Research Foundation
iThemba LABS Laboratory for Accelerator Based Sciences

What is AI_r?

An air quality monitoring, analysis and prediction system.

AI_r will make access to air quality monitoring and AI-powered prediction equitable by lowering the barriers to entry for developing countries.

AI_r combines power optimized air quality sensors with a low-cost Internet-of-Things (IoT) network architecture and Artificial Intelligence (AI)

The emerging technologies AI and IoT have provided the ability to make decisions and predictions around public health, risk management, and governance.

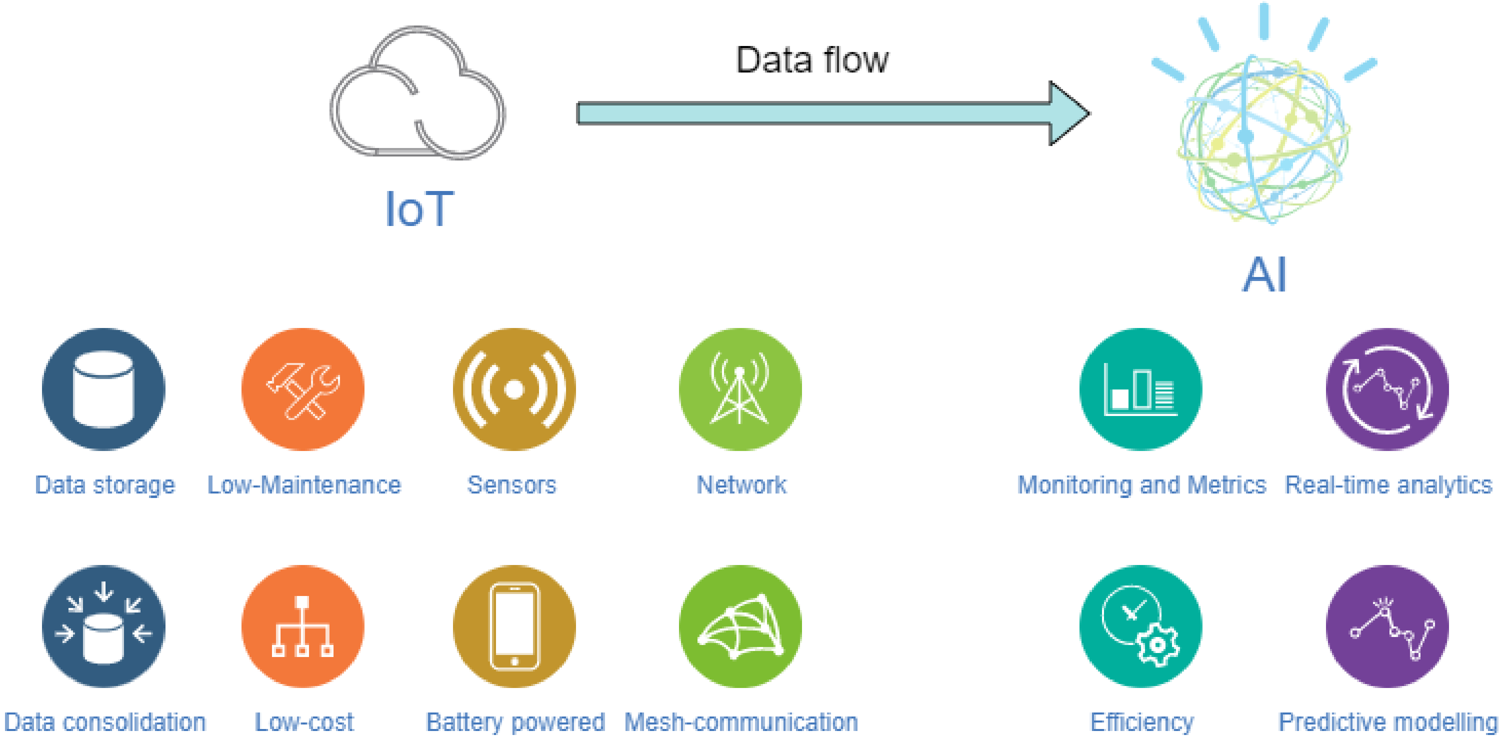
AI_r will offer functionality suited to both developing and developed countries thereby constituting a global air quality solution.

AI_r will augment current national air quality monitoring systems by providing hundreds of thousands of additional sensor nodes.

The low cost per unit allows for a highly scalable system

AI_r Overview

- AI_r is envisioned to address shortcomings in currently available commercial systems.
- A high-level view of the AIoT Air Quality Monitoring Systems' key attributes can be seen in Figure 3.



IoT Sensor node

We want to emulate as many key aspects as possible the IoT application for air quality

Triggering
- Via local PIR

Sensors
- Temperature, humidity and optical

Local Intelligence
- Nordicn nRF52840 SoC

Wireless communication
Nordic nRF52840 Dongle

- The figure on the right displays a computer aided design of a IoT device that has been optimized for low-cost production and low-energy consumption.
- The device is centered around the Nordic nRF52840 Dongle.

Fig. **Nordic nRF52840 Dongle** , ***Credit: Nordic Semiconductor***

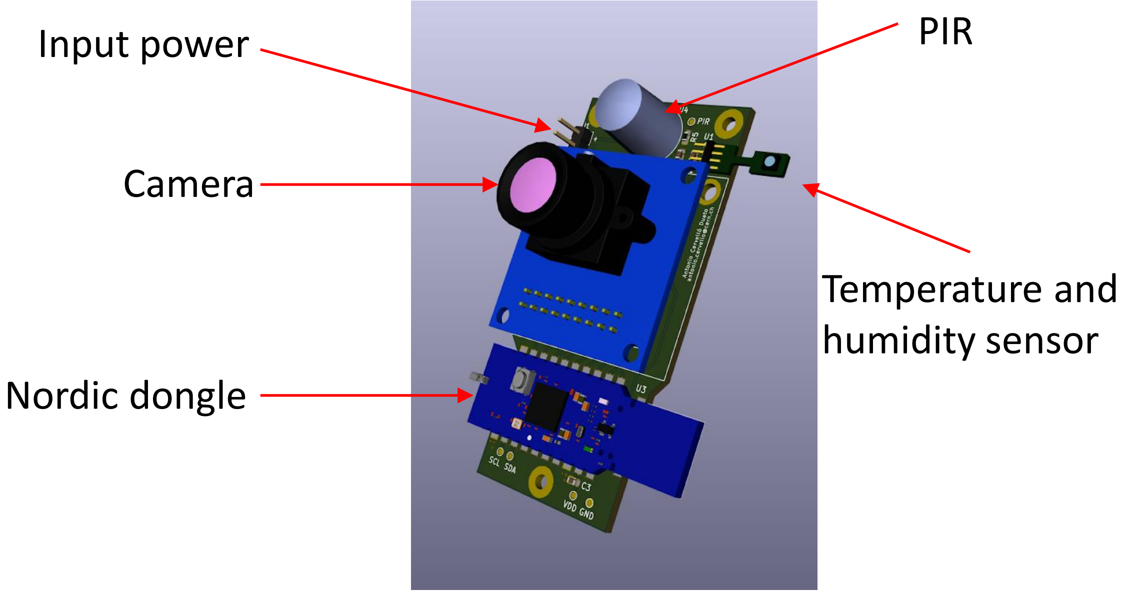


Fig. A computer aided design of a sensor node, Antonio Duato

IoT node – prototyping

The development of an IoT node follows a standardized process:

- The use of a development board and peripherals allows for the rapid commencement of work.
- Computer aided design is then utilized for the design of the node.
- An inhouse prototype PCB is produced allowing for the design to be validated.
- The PCBs are produced by a manufacturer and are then populated.

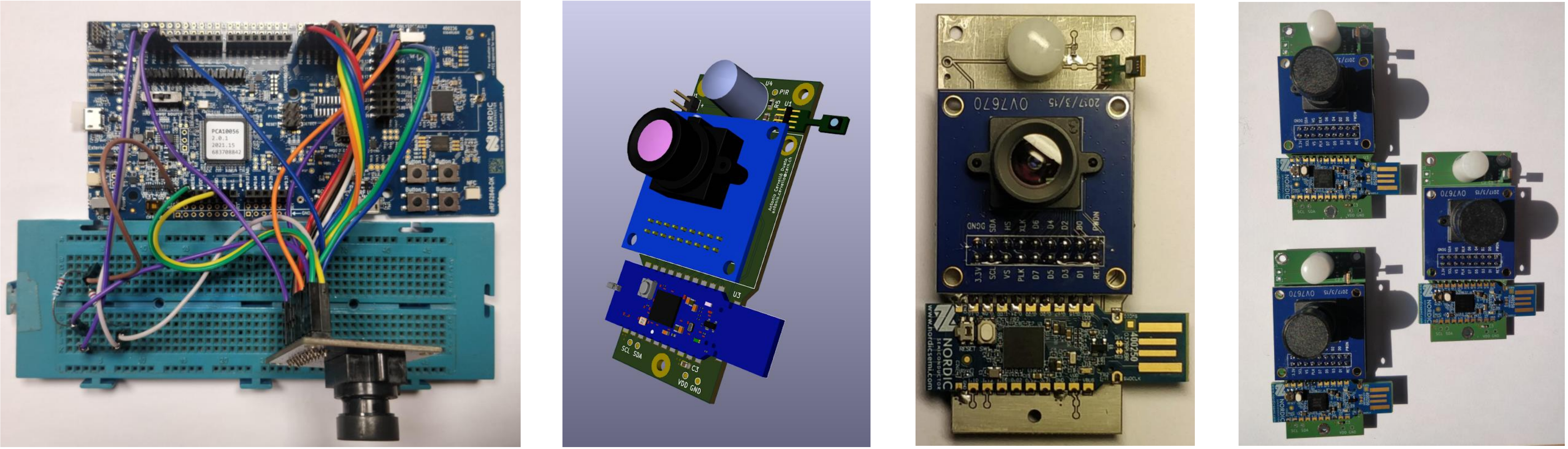


Fig. The evolution of an IoT node prototype, Antonio Duato

Prototype IoT Air quality sensors

The selection of the sensor suite will be dependent on numerous factors:

- Consultation with relevant stakeholders to finalize criteria pollutants and their required measurement range, precision and accuracy.
- Power consumption optimization
- The systems sensor suite can be tailored to the specifics of the country and/or region that which it is deployed. The sensors can also be fine-tuned to focus on particular pollutants sources such as motor vehicles.

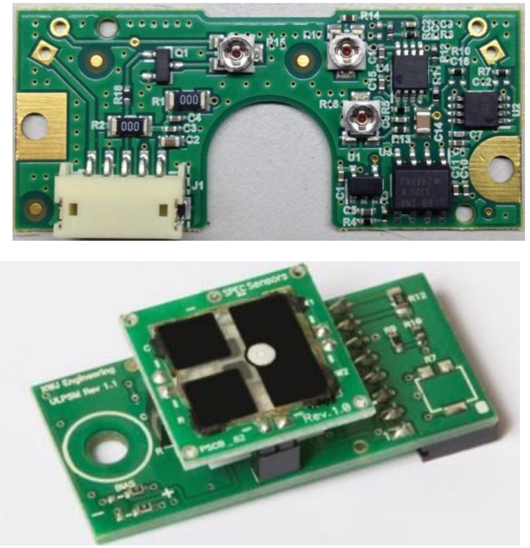


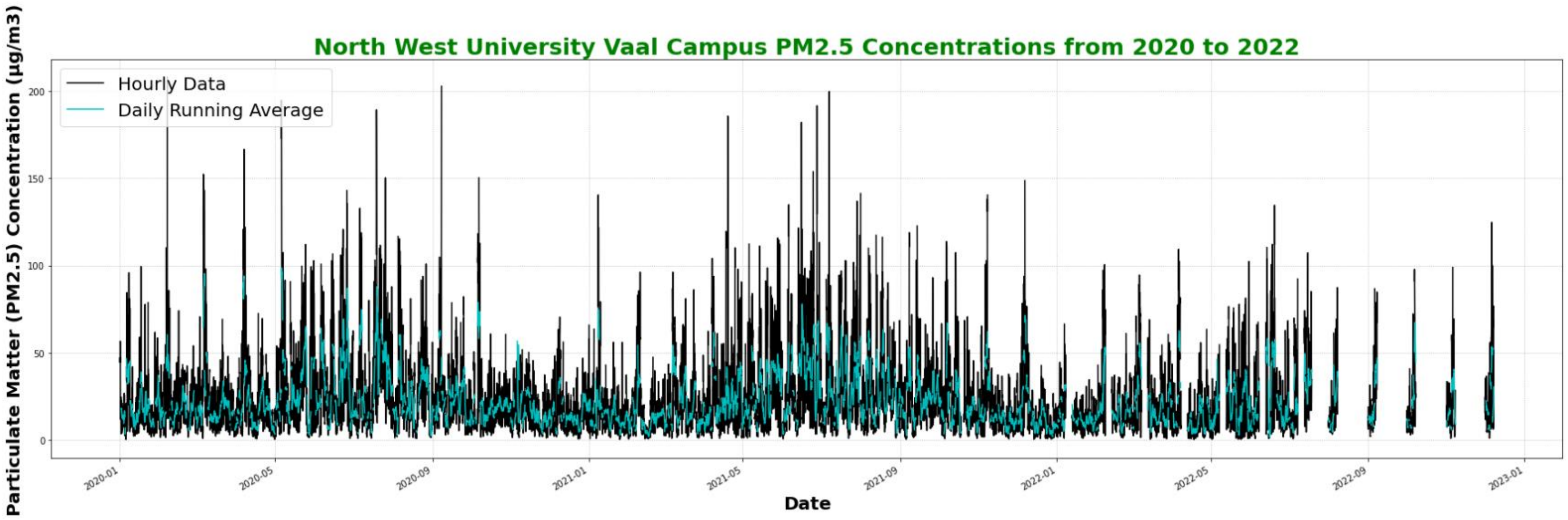
Fig. ULPSM-SO2 968-00 S02 sensor (Top). Credit: Spec sensors. TIDA-00378 PM2.5/10 particle sensor (Bottom). Credit: Texas Instruments.

Fig. Perovskia solar cell. PEROVSKIA SOLAR - Products

nRF9160 - Nordic Semiconductor - nordicsemi.com

Towards Implementation of AI on SAAQIS Data

- Data scraping of the air quality data stored on the SAAQIS website is the first step towards AI implementation.
- Data scraping has been successfully conducted on the SAAQIS website.
- Pre-processing of the data is ongoing.
- Preparations for DNN training is ongoing.



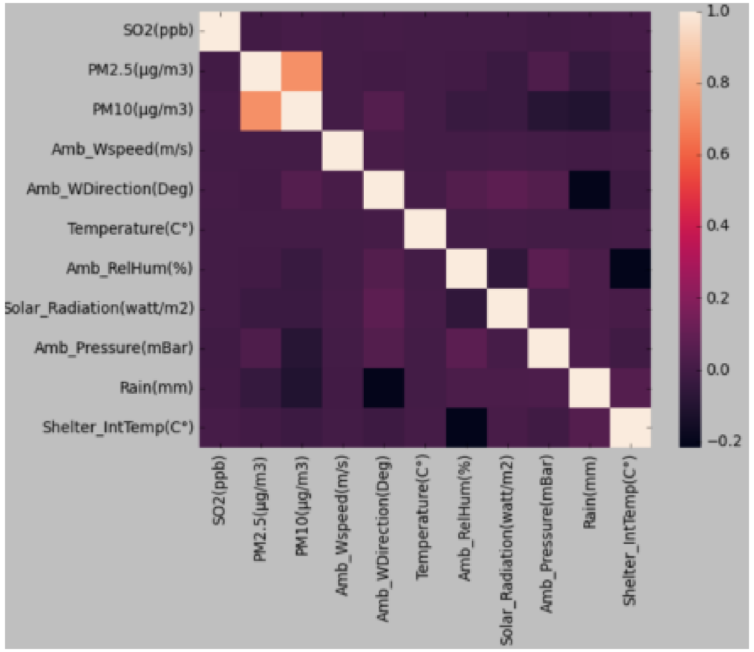


Fig. A correlation plot of data captured by SAAQIS in Gauteng, Malusi Msweli and Vongani Chabalala.

The CERN campus: The perfect test-bed

- The high-use Route de Meyrin that connects Saint-Genis Pouilly and Geneva has been identified as a region for deployment,
- The route bisects the CERN Meyrin campus and is a busy arterial road that is frequented by CERN staff, Users, as well as tourists visiting CERN.

Fig. A google maps image illustrating the traffic density of the Route de Meyrin. Credit: Google maps.

Summary

SACAQM
AI_r

- Air quality is a growing global concern.
- The South African Consortium of Air Quality Monitoring has been formed to address this concern.
- Current Air quality monitoring systems are not fit for purpose due to many limitations.
- The AI_r air quality monitoring, analysis and prediction system is currently being developed.

http://www.sacaqm.org

Supplementary slides

Identification of Air pollutants of concern

- Preliminary pollutants be must include those for which National Ambient Air Quality Standards have been set.
- Different standards are set by each country as well as the World Health Organization.
- Particulate Matter (PM) is a common proxy indicator for air pollution.
- PM10, 2.5 and S02 will be the first pollutants to be monitored by AI_r.

SO2

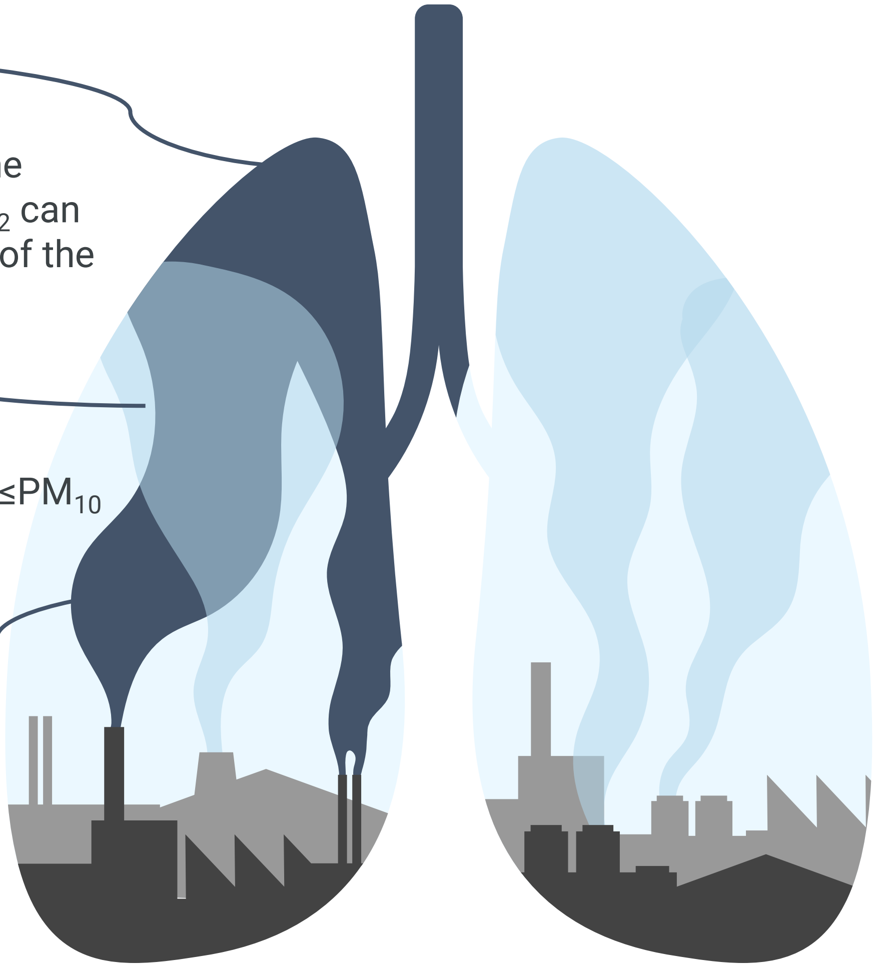
SO_2 is a colorless gas with a sharp odor. It is produced from the burning of fossil fuels and the smelting of mineral ores that contain sulfur. SO_2 can affect the respiratory system and the functions of the lungs and causes irritation of the eyes.

PM10

Particles with a diameter of 10 microns or less, $\leq PM_{10}$ can penetrate and lodge deep inside the lungs

PM2.5

With a diameter of 2.5 microns or less, ($\leq PM_{2.5}$). $PM_{2.5}$ can penetrate the lung barrier and enter the blood system.



Ambient (outdoor) air pollution (who.int)

Schadstoff	Immissionsgrenzwert	Statistische Definition
Schwefeldioxid (SO_2)	30 µg/m³ 100 µg/m³ 100 µg/m³	Jahresmittelwert (arithmetischer Mittelwert) 95 % der ½-h-Mittelwerte eines Jahres ≤ 100 µg/m³ 24-h-Mittelwert; darf höchstens einmal pro Jahr überschritten werden
Stickstoffdioxid (NO_2)	30 µg/m³ 100 µg/m³ 80 µg/m³	Jahresmittelwert (arithmetischer Mittelwert) 95 % der ½-h-Mittelwerte eines Jahres ≤ 100 µg/m³ 24-h-Mittelwert; darf höchstens einmal pro Jahr überschritten werden
Kohlenmonoxid (CO)	8 mg/m³	24-h-Mittelwert; darf höchstens einmal pro Jahr überschritten werden
Ozon (O_3)	100 µg/m³ 120 µg/m³	98 % der ½-h-Mittelwerte eines Monats ≤ 100 µg/m³ 1-h-Mittelwert; darf höchstens einmal pro Jahr überschritten werden
Schwebestaub (PM10) ¹) **Blei** (Pb) im Schwebestaub (PM10) **Cadmium** (Cd) im Schwebestaub (PM10)	20 µg/m³ 50 µg/m³ 500 ng/m³ 1,5 ng/m³	Jahresmittelwert (arithmetischer Mittelwert) 24-h-Mittelwerte; darf höchstens einmal pro Jahr überschritten werden Jahresmittelwert (arithmetischer Mittelwert) Jahresmittelwert (arithmetischer Mittelwert)
Staubniederschlag insgesamt **Blei** (Pb) im Staubniederschlag **Cadmium** (Cd) im Staubniederschlag **Zink** (Zn) im Staubniederschlag **Thallium** (Tl) im Staubniederschlag	200 mg/(m²xTag) 100 µg/(m²xTag) 2 µg/(m²xTag) 400 µg/(m²xTag) 2 µg/(m²xTag)	Jahresmittelwert (arithmetischer Mittelwert) Jahresmittelwert (arithmetischer Mittelwert) Jahresmittelwert (arithmetischer Mittelwert) Jahresmittelwert (arithmetischer Mittelwert) Jahresmittelwert (arithmetischer Mittelwert)

mg = Milligramm; 1 mg = 0,001 g
µg = Mikrogramm; 1 µg = 0,001 mg
ng = Nanogramm; 1 ng = 0,001 µg
Das Zeichen ≤ bedeutet "kleiner oder gleich"
¹) Feindisperse Schwebestoffe mit einem aerodynamischen Durchmesser von weniger als 10 µm.

Table. Table of the current Swiss air quality. Credit: NABEL

Towards Implementation of AI on SAAQIS Data