Bosch
Air Quality Solutions

Monitor. Understand. Improve.

We significantly contribute to life quality and environmental protection by improving air quality.

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Our air quality solutions

We monitor, understand, improve and validate to enable excellent solutions through our products and services.

Transmission
Influencer

Emissions
Sender

Air Quality
Recipient

Environmental Sensitive Traffic Management (ESTM)

Reduction of emissions in densely-populated urban centres through modelling and sustainable measures

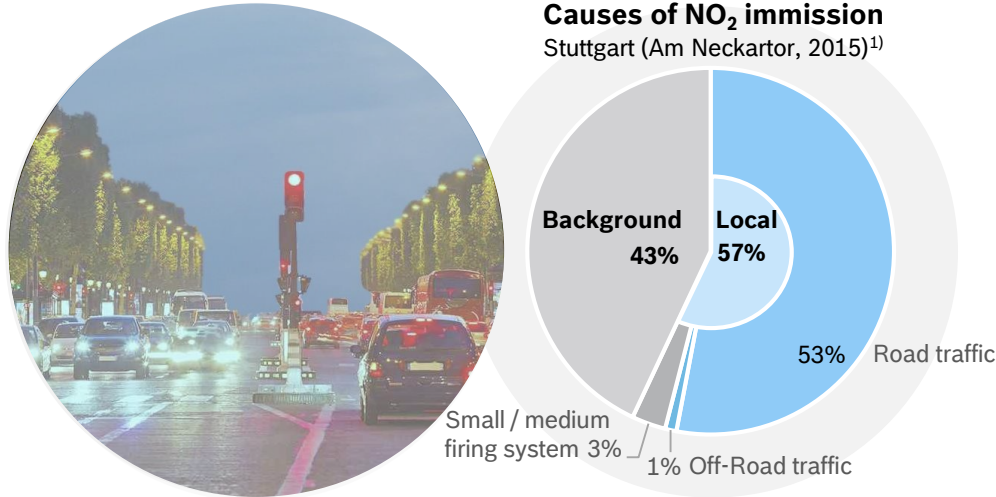**Comprehensive capture & track of air quality (Eco-Loop)**

Enabler for tailor-made and sustainable measures for emission-critical hotspots by considering real-time air quality maps, dispersion and environmental parameters

Immission Monitoring Box (IMB)

Monitoring enables precise, real-time air quality maps and the definition of measures accordingly

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Environmental Sensitive Traffic Management (ESTM)

We change the driving behaviour by minimizing accelerations and by focusing on continuous traffic flow and less stops.

Causes of NO_2 immission
Stuttgart (Am Neckartor, 2015)[1]

Background 43%

Local 57%

53% Road traffic

Small / medium firing system 3%

1% Off-Road traffic

Problems we are addressing with our solution

↗ **Up to 7 times** higher NOx emissions (averaged) in accelerations between 0 and 20km/h compared to continuous driving between 40 and 140 km/h[1]

☁NOx **Up to 77%[2]** of NO_2 immission through road traffic

[1]Source: Landesumweltamt BW
[2] road traffic: local 53%, background 24%

Our solution offers

Microscopic
emission source modelling

High-resolution
emission maps (20m/1h) for CO_2, NO_2 & PM
based on real-time driving behaviour of urban traffic

Scalable
from entire city to single crossroads;
All vehicle categories can be represented (EU1 – EU6)

Optimized
traffic flow by targeted measures (ESTM)
based on precisely recording & analysis

Reduced
emissions on critical emission hotspots and city-wide,
as well of vehicle numbers

Improvement
Proof of concept shows up to 20% NO_2 reduction

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Environmental Sensitive Traffic Management (ESTM)

We reduce emissions, particularly in densely populated urban areas, by optimizing traffic management to our customers.

City traffic data + **Real time data of engine and driving state** + **AQ data** ❯ **Microscopic, real-time emission modelling***

*for CO_2, NO_2, PM

Live data of emissions are extrapolated with live traffic volume data; the emission model is scalable from the entire city area to a single crossroad.

⬇

Improving air quality through traffic management at high emission locations by focusing on:

Minimize accelerations, continuous traffic flow, less stops and

enhancement of new mobility solutions (rerouting)

🍃 **led to 20% improvement in NO_2 emissions in city project**
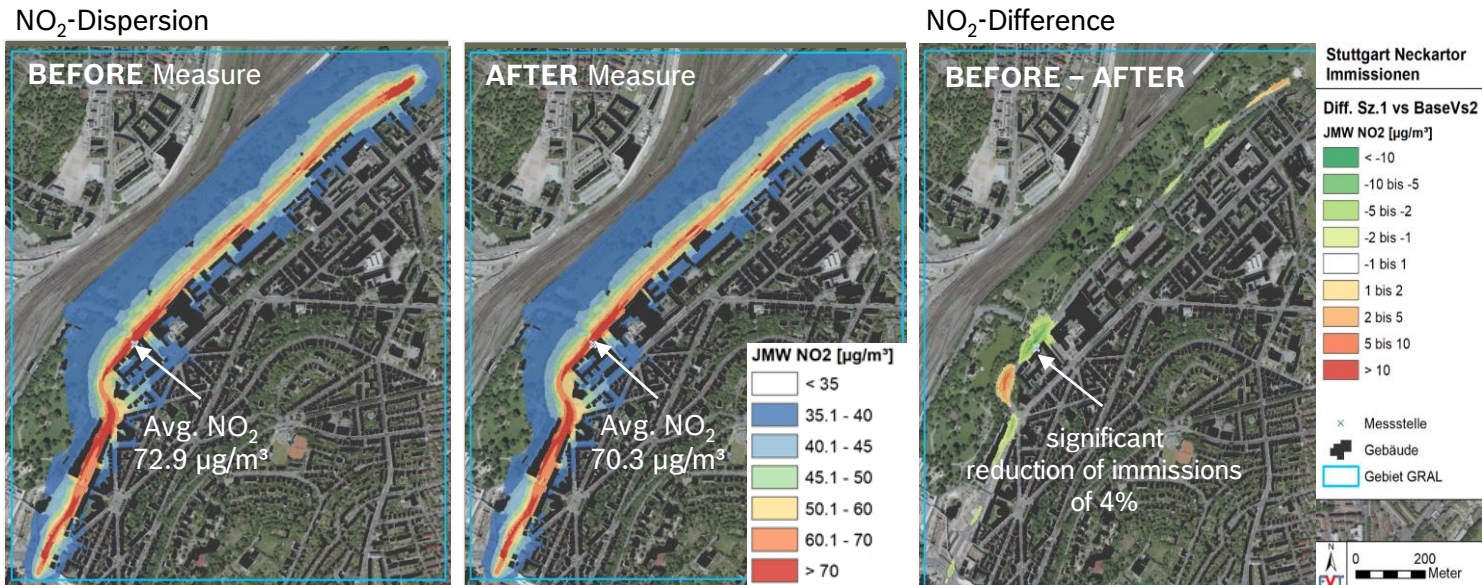
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Environmental Sensitive Traffic Management (ESTM)

We provide mobility solutions quantifying / proving benefits for both emission and air quality values.

Improving air quality through traffic management

led to 20% improvement in NO_2 emissions

🖋 **and to 4% improvement in NO_2 immissions in city project**

NO_2-Dispersion

NO_2-Difference

BEFORE Measure — Avg. NO_2 72.9 µg/m³

AFTER Measure — Avg. NO_2 70.3 µg/m³

BEFORE – AFTER — significant reduction of immissions of 4%

Example: Stuttgart Neckartor, Germany

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Eco-Loop: comprehensive capture and track of air quality

We close the gap between emission, the sender, and air quality, the recipient.

Eco-Loop
Influencer

3D-Transport calculation

Buildings topologies

Meteorological Distribution

Fleet data

AQ data

Emissions
Sender

Air Quality
Recipient

Immission Heat maps

Real time
high resolution
air quality maps

spatial (5m) & time (1h)

Example: Ludwigsburg, Germany

NO_2

PM_{10}
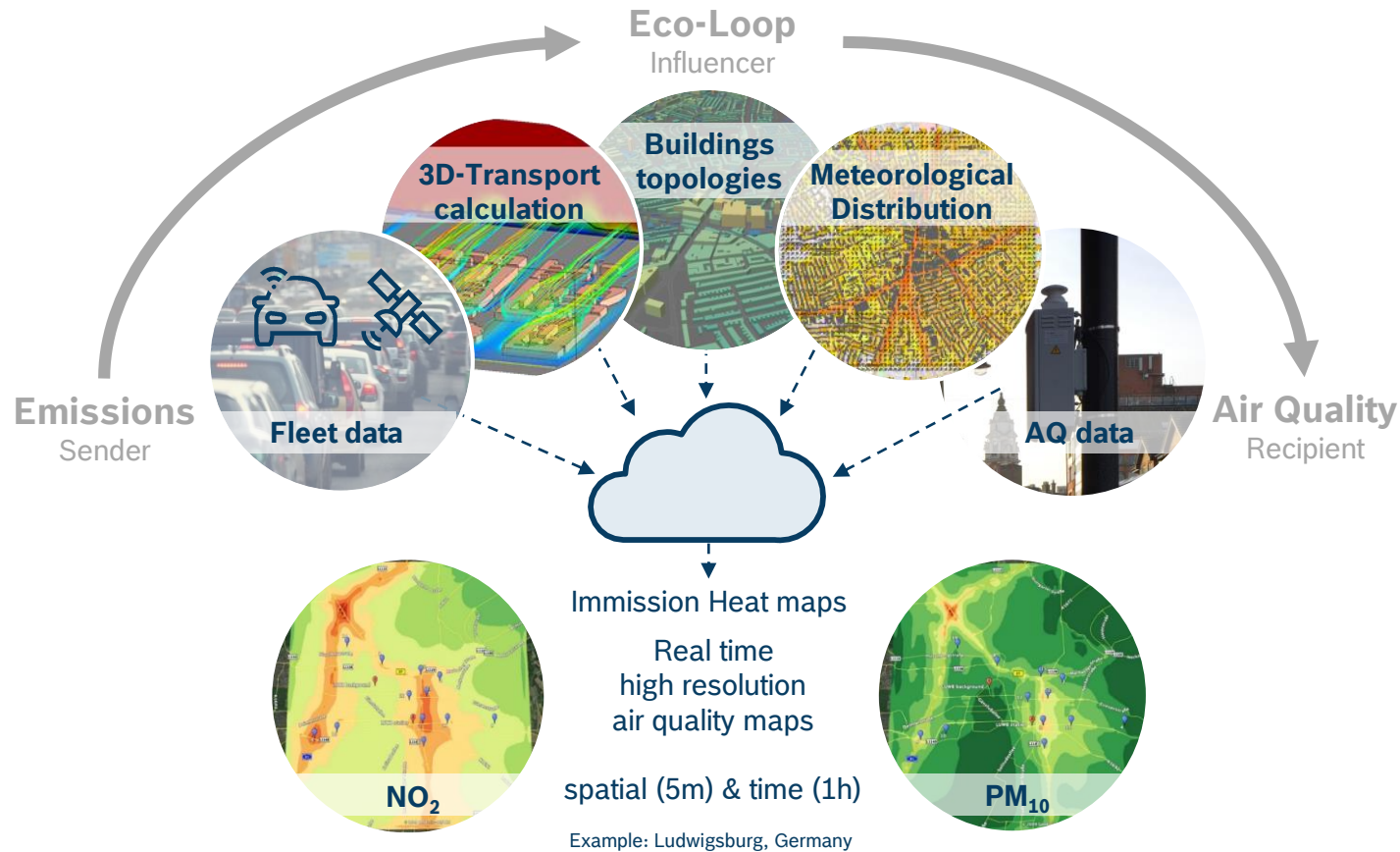
Bosch IoT Cloud Services

Data quality due to
- Simulation software and algorithms based on artificial intelligence
- Complex diffusion and reaction processes in the atmosphere
- High resolution 3D immission propagation calculations

Data security & reliability
- Compliance with privacy policies
- Highest standards

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Immission Monitoring Box (IMB)

We monitor with a high precision measurement device to gain an accurate view of the air quality and to identify pollution sources.

Immission Monitoring Box (IMB)

Parameters

Gases: NO_2, O_3, CO, SO_2

Particles: $PM_{2.5}$ and PM_{10}

Air data: relative humidity (RH), temperature, pressure

Certified

according to EU air quality directive 2008/50/EC (39. BImSchV) and BOSCH guaranty for data accuracy over life-time. [1]

Accurate

air quality monitoring with high time and spatial resolution.

Local measurement data

can be send to the cloud for analysis and further processing; wireless data connectivity offers remote monitoring.

Robustness

towards disturbances[2] due to intelligent correction functions and HW measures.

Sustainability

draw up precise air quality dispersion maps, make forecasts and enable emission sensitive traffic management to improve. [3]
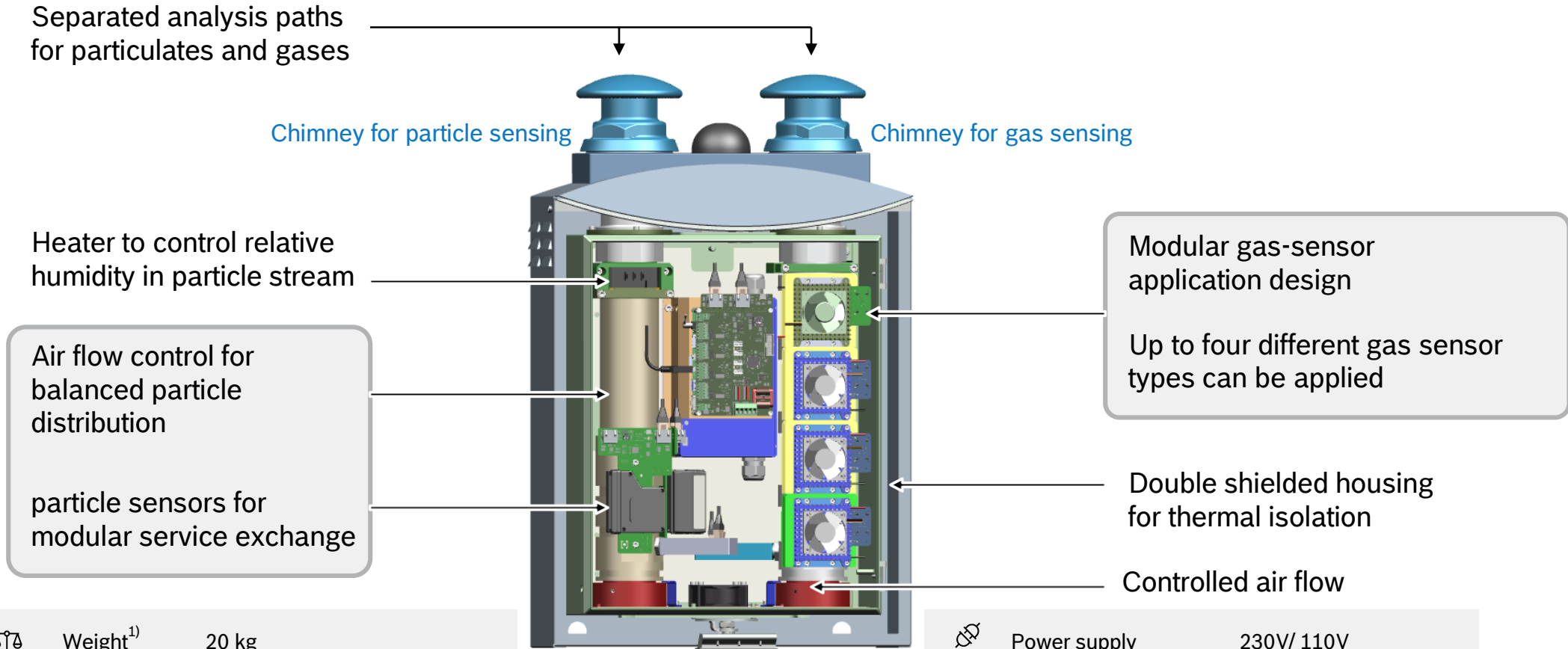
[1] through external test laboratory
[2] e.g. humidity, temperature
[3] By installing a network of IMBs, an Immission Monitoring System (IMS)

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IMB: key design features

During a long research and engineering phase we achieved design solution to provide best sensor data already in our raw data

Separated analysis paths for particulates and gases

Chimney for particle sensing

Chimney for gas sensing

Heater to control relative humidity in particle stream

Modular gas-sensor application design

Up to four different gas sensor types can be applied

Air flow control for balanced particle distribution

particle sensors for modular service exchange

Double shielded housing for thermal isolation

Controlled air flow

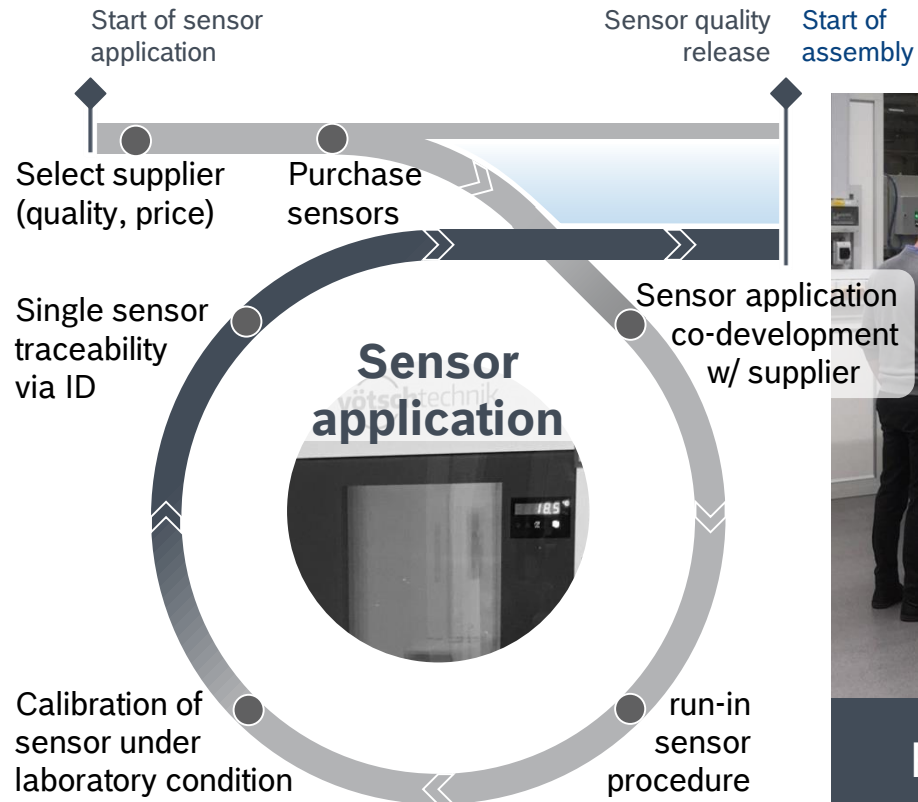|		
Weight[1]	20 kg	
Dimensions	663,5 x 420 x 233,5 mm³	
Power supply	230V/ 110V	
Power consumption	Typical 50W; Max 200W	

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IMB: quality standards in production & market testing

Within our pre-, in- and post-production steps we lay the foundation for providing a best-in-class ambient air monitor to the market

Start of sensor application

Sensor quality release

Start of assembly

Product quality release

Start of market capability check

Release to market

Select supplier (quality, price)

Purchase sensors

case study

Low cost monitors

this differs us from low cost monitors

BOSCH IMB

Sensor application

Assembly & release

Market release

Ongoing feedback loop improving the production process

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IMB: quality standards in sensor application

For us the sensor application starts with the supplier selection and ends with handing over calibrated sensors for final assembly
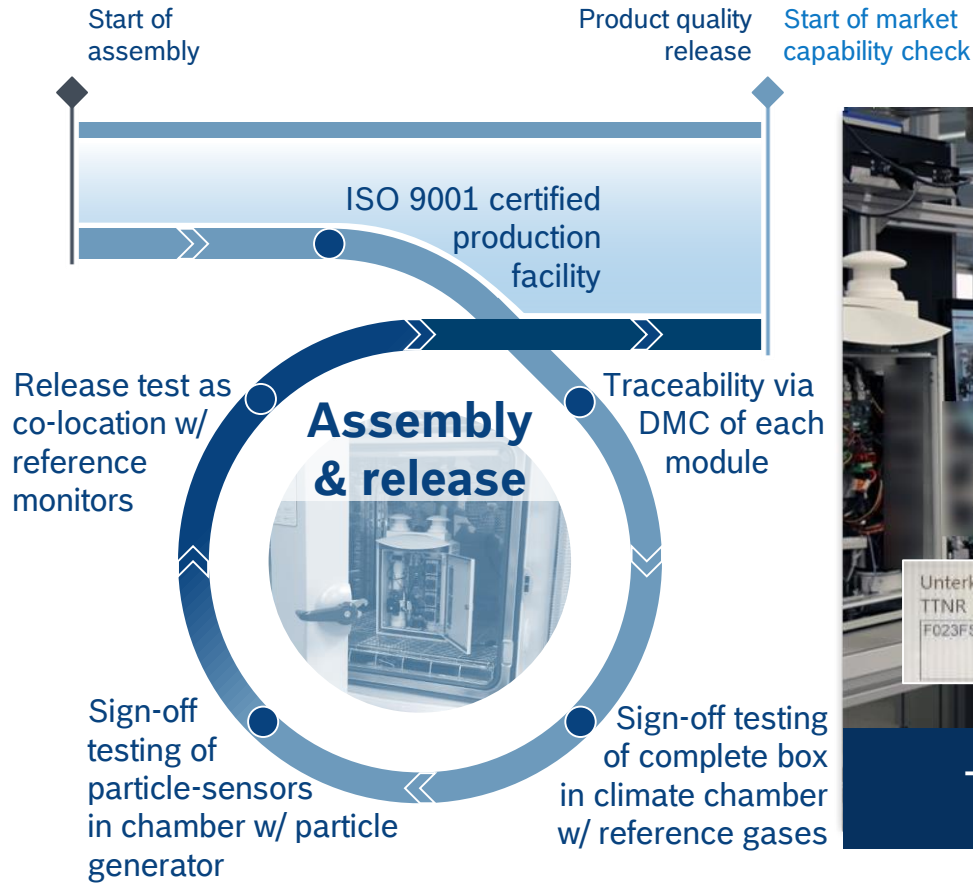
Start of sensor application

Sensor quality release

Start of assembly

Select supplier (quality, price)

Purchase sensors

Single sensor traceability via ID

Sensor application co-development w/ supplier

Sensor application

Calibration of sensor under laboratory condition

run-in sensor procedure

Run-in sensor procedure

Calibration in reference atmosphere

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IMB: quality standards in assembly and release testing

Keeping traceability during assembly and test-releasing the final product as a whole is the core of our production process

Start of assembly

Product quality release

Start of market capability check

ISO 9001 certified production facility

Assembly & release

Release test as co-location w/ reference monitors

Traceability via DMC of each module

Sign-off testing of particle-sensors in chamber w/ particle generator

Sign-off testing of complete box in climate chamber w/ reference gases

Particle testing & release chamber

Traceability via DMC

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IMB: quality standards for market testing and release

Gaining robustness of our monitor during the development phase was proved by achieving a certificate in Q2/2020

In field co-location w/ reference stations **across world**

Passing certification test procedure
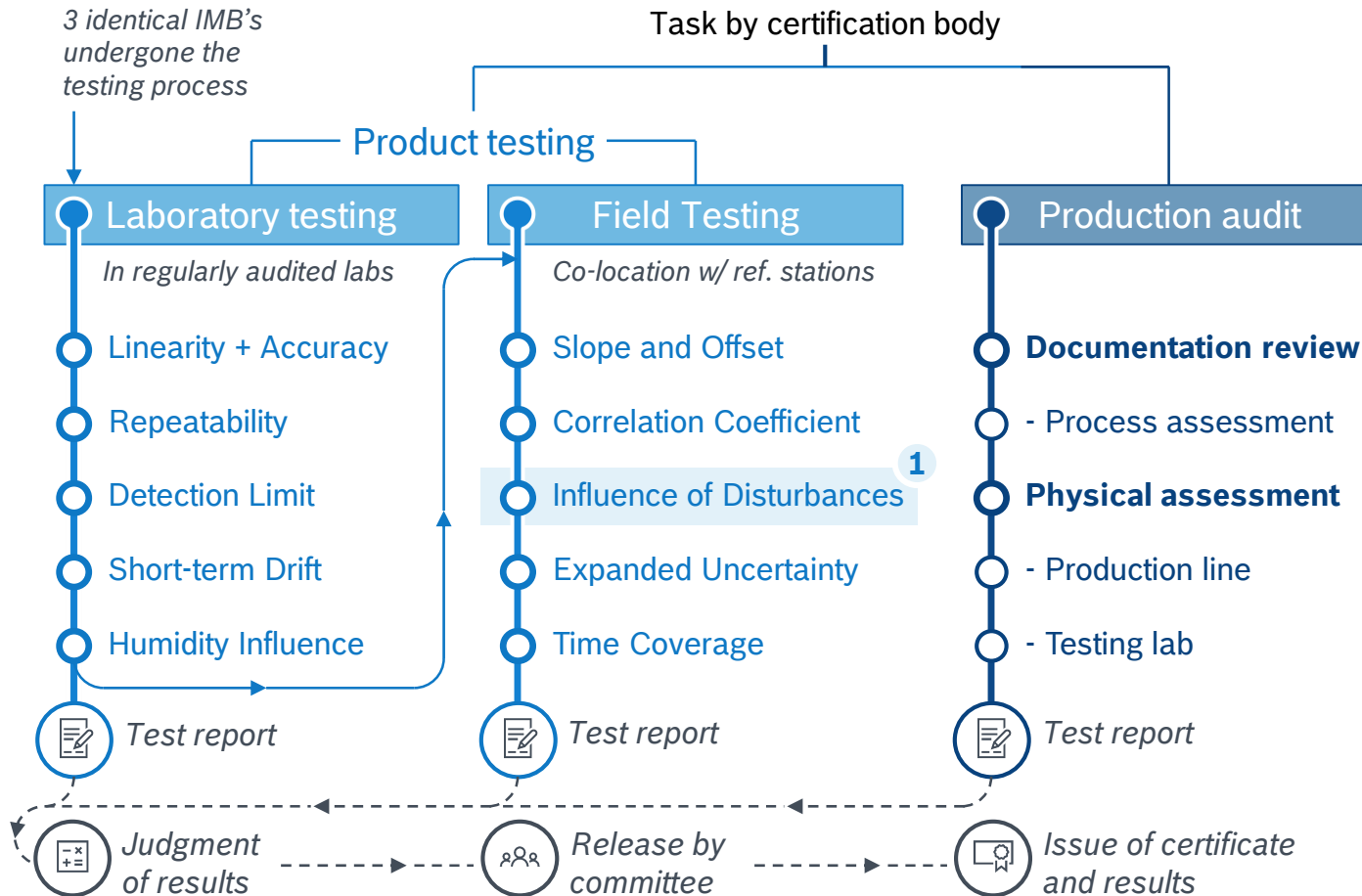
Product quality release
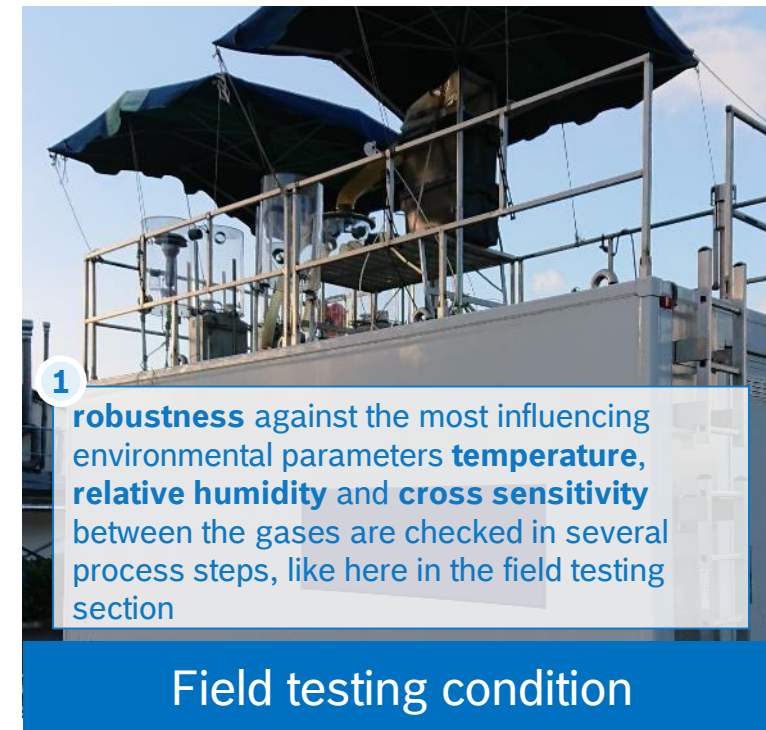
Start of market capability check

Release to market

case study

Low cost monitors

Certification in Q2/20

BOSCH IMB

Co-location testing of samples since 2018

Market release

case study demo "London" w/ production parts Q1/20

field testing in E2019 w/ pre-production samples

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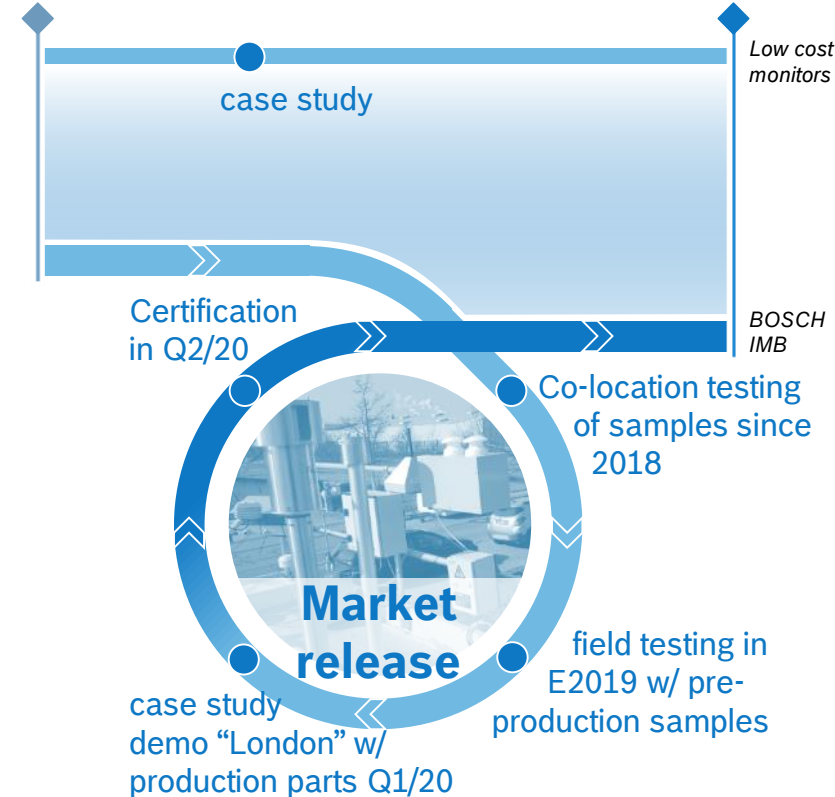
IMB: insights on Certification Process

The main structure and steps of the established certification process* for ambient air monitors (e.g. VDI 4202) were applied

3 identical IMB's undergone the testing process

Task by certification body

* detailed certification criteria expected to be released by the certification body in 08/2020

Product testing

Laboratory testing	Field Testing	Production audit
In regularly audited labs	*Co-location w/ ref. stations*	
Linearity + Accuracy	Slope and Offset	**Documentation review**
Repeatability	Correlation Coefficient	- Process assessment
Detection Limit	Influence of Disturbances [1]	**Physical assessment**
Short-term Drift	Expanded Uncertainty	- Production line
Humidity Influence	Time Coverage	- Testing lab
Test report	Test report	Test report

Judgment of results → *Release by committee* → *Issue of certificate and results*

[1] **robustness** against the most influencing environmental parameters **temperature, relative humidity** and **cross sensitivity** between the gases are checked in several process steps, like here in the field testing section

Field testing condition

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IMB: example of field data

Exemplary data from London for NO_2 and PM10 compared to a reference station nearby
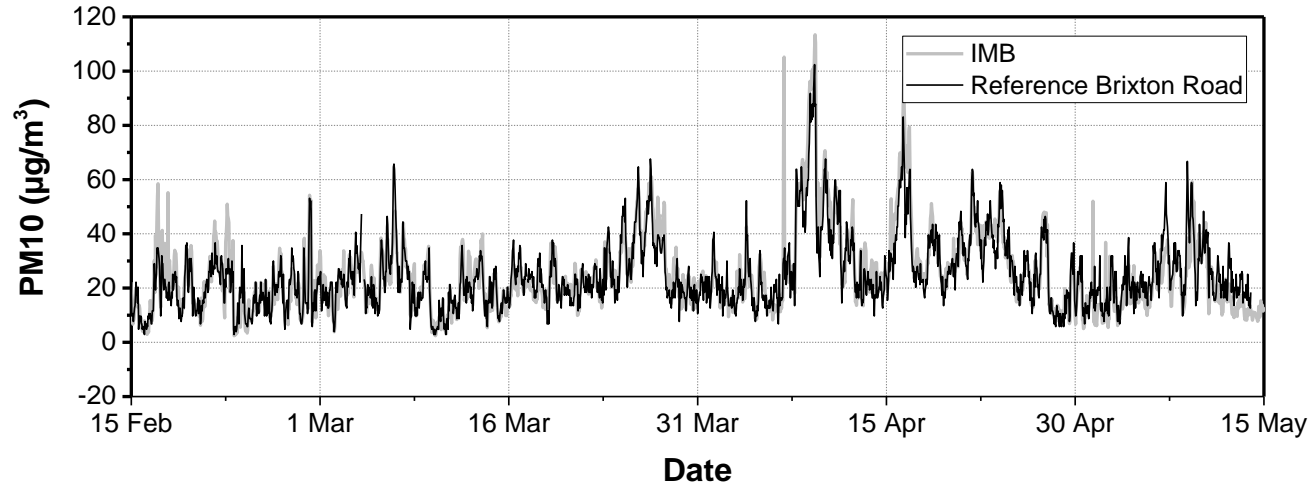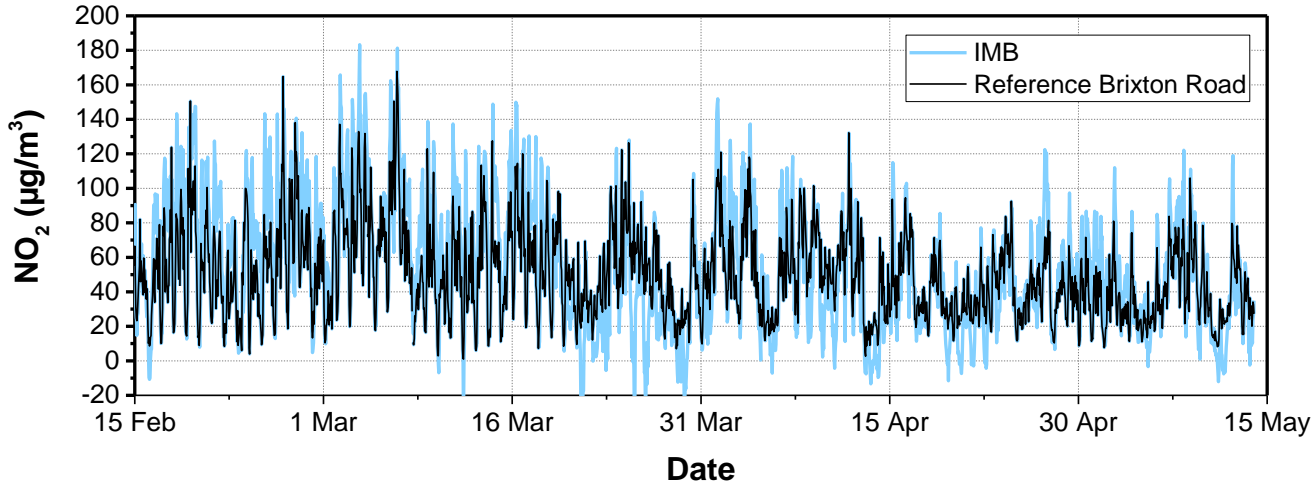
Data shown for substances of NO_2 and PM10 the performance level of the IMB as a stand-alone monitor:

- **good correlation** w/ reference monitoring devices over 3 months in **cold** and rainy **condition**

- **Correction** are applied on the device by the **build-in measures** – no post-processing applied to data

U = 30%
Relative expanded uncertainty

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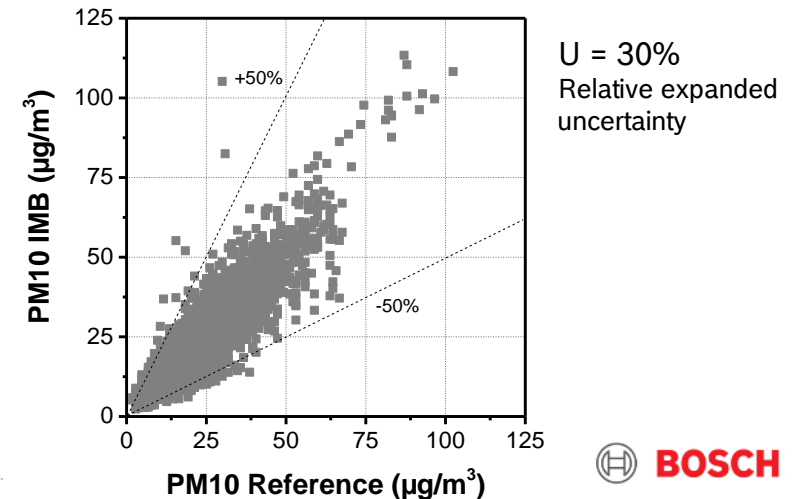
IMB: product life-cycle and service model

We guarantee the data quality for our customers through a suitable business model.

Production

Weight[1]   20 kg

Dimensions   663,5 x 420 x 233,5 mm³

[1] Actual sample

IMB produced and calibrated 'End of Line' in Germany

Operation

Data transfer &
cloud storage[2]

via GSM in Bosch IoT Cloud

[2] Server located in Germany

Customers provide electricity & installation place

Service

IMB sensors
- ✓ Checking
- ✓ Re-calibration and / or
- ✓ Replacement

Service interval: annually

Flexible quality for our customers

Purchase   Purchase of the HW. Separate contract for data service: data transfer and cloud storage.

Leasing   Leasing[3] of the IMB incl. data transfer, cloud storage and sensor service[4].   [3] in Germany; [4] for leasing duration more than 1 year

Service   Checking, re-calibration and / or replacement of sensors; as add-on to purchase.

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IMB: monitoring grid layout criteria

The monitoring grid is mostly driven by the application driver slogan "If you don't measure it – you can't manage it – you will not fix it"

measure

RB case study: City of Russelsheim (DE)
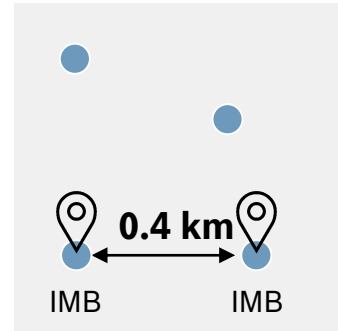
Use case: local **spot check monitoring**
for

IMB

1.2 km

IMB
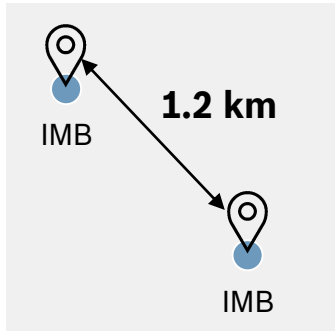
Grid density: high — mid — low

manage

RB case study: City of Ludwigsburg (DE)

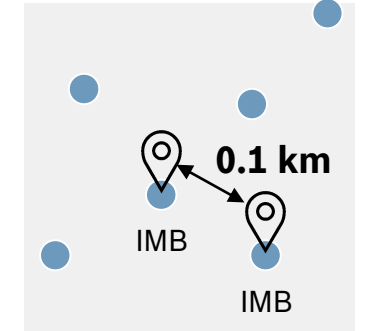Use case: **continuous AQ monitoring** in urban area (heat map creation)
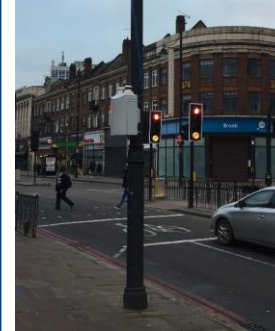

IMB **0.4 km** IMB

Grid density: high — mid — low

fix

RB case study: Traffic for London (UK)

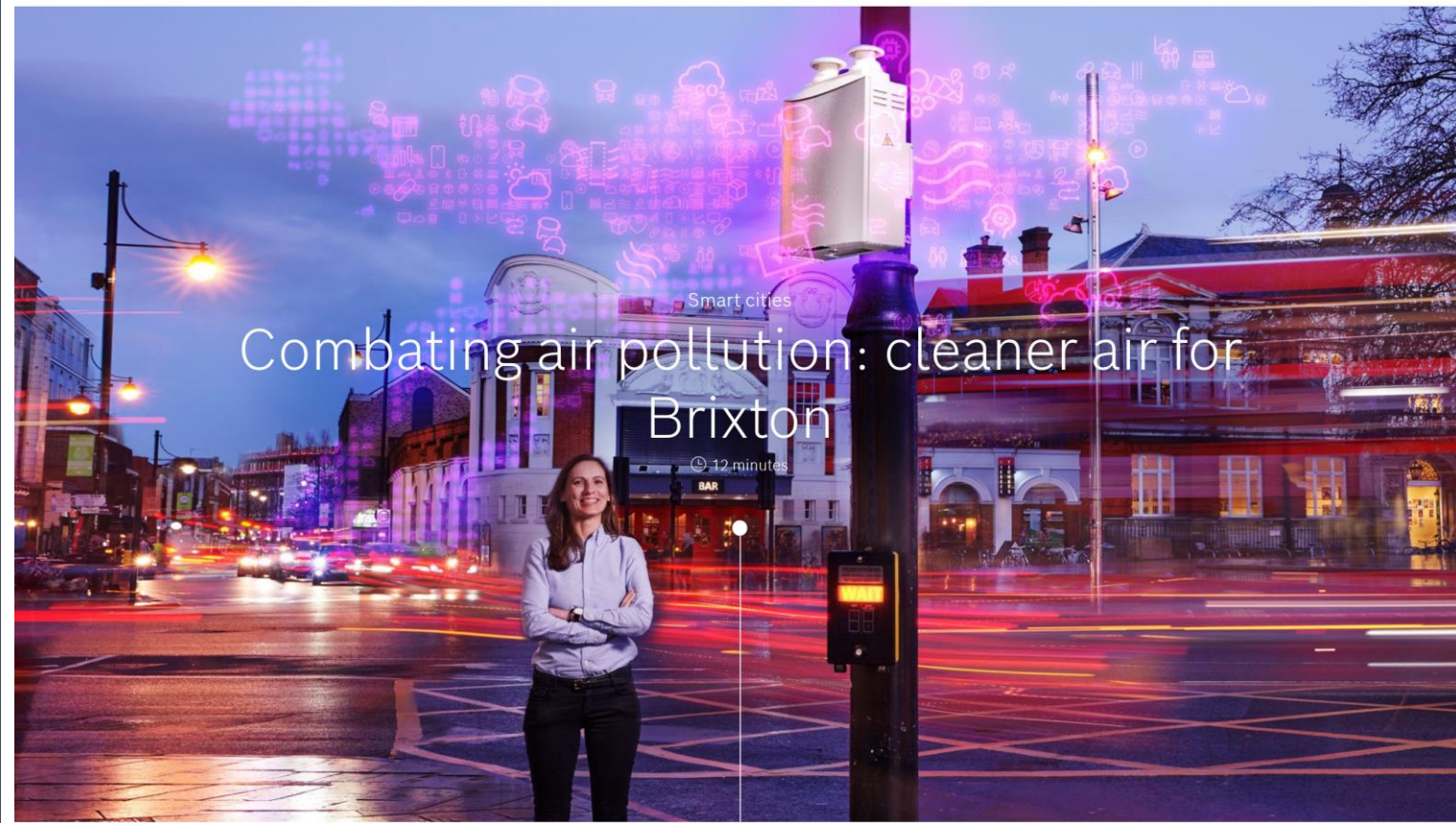Use case: **spot check monitoring** to proof effectiveness of applied measure

0.1 km

IMB

IMB

Grid density: high — mid — low

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Impressions of the IMB in urban areas

We monitor and validate the air quality in London: LINK to the article

https://www.bosch.com/stories/measures-to-reduce-air-pollution/

Smart cities

Combating air pollution: cleaner air for Brixton

12 minutes

### Precise mapping is key to improved air quality

The technology being used in a roughly four square-kilometer area bordering Brixton Road is designed to analyze the pollution caused by traffic and to forecast how it will be dispersed. If measures to combat air pollution are to be effective, they need to be based on a sound understanding of what causes it, how it spreads, and how it changes during the course of the day.

The cornerstones of the London project are 17 air quality monitoring boxes. Measuring 60 centimeters high and 40 centimeters across, they contain a range of sensors including various gas and particle sensors and sensors for humidity, temperature, and pressure: "The boxes measure levels of nitrogen dioxide and particulate matter, humidity, and ambient temperature, among other things," says Martinez Prada, who has a PhD in sensor technology. The data is then uploaded to a Bosch cloud—the brains, as it were, of the air quality solution.

Brixton Road often records nitrogen dioxide levels well in excess of prescribed limits.

Sources of data for AI
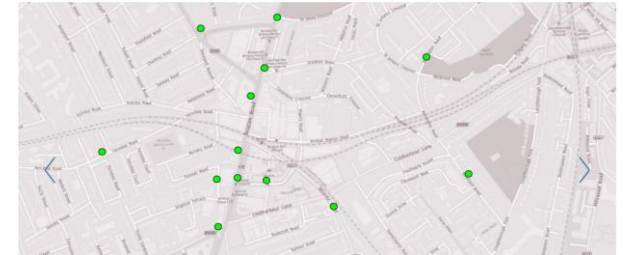
London is only the beginning

The precise monitoring solution can also be used at specific locations such as schools and day-care centers. Real-time monitoring and forecasts of air pollution can allow outdoor activities such as physical education classes to be scheduled better. It also opens up new opportunities for additional applications of this technology in the growing market for smart campuses—so-called because they make use of intelligent, connected solutions. For example, the statistics provided by Bosch monitoring boxes could be used to control smart ventilation systems. If results show that summer air quality is better outdoors than indoors, windows can be opened automatically and the energy-intensive ventilation system switched off. This reduces energy consumption and, consequently, CO_2 emissions.

The Bosch system in place on Brixton Road can also help improve air quality at other locations.

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