ICLEI Local Governments for Sustainability

CoCO2 Prototype system for a Copernicus CO_2 service

City Workshop

High Resolution Emission Inventories in Near Real Time for Cities

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CARBON MONITOR

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Carbon Monitor : an international initiative

Mission : Deliver accurate CO_2 emissions estimates with global coverage, low latency and high space / time resolution

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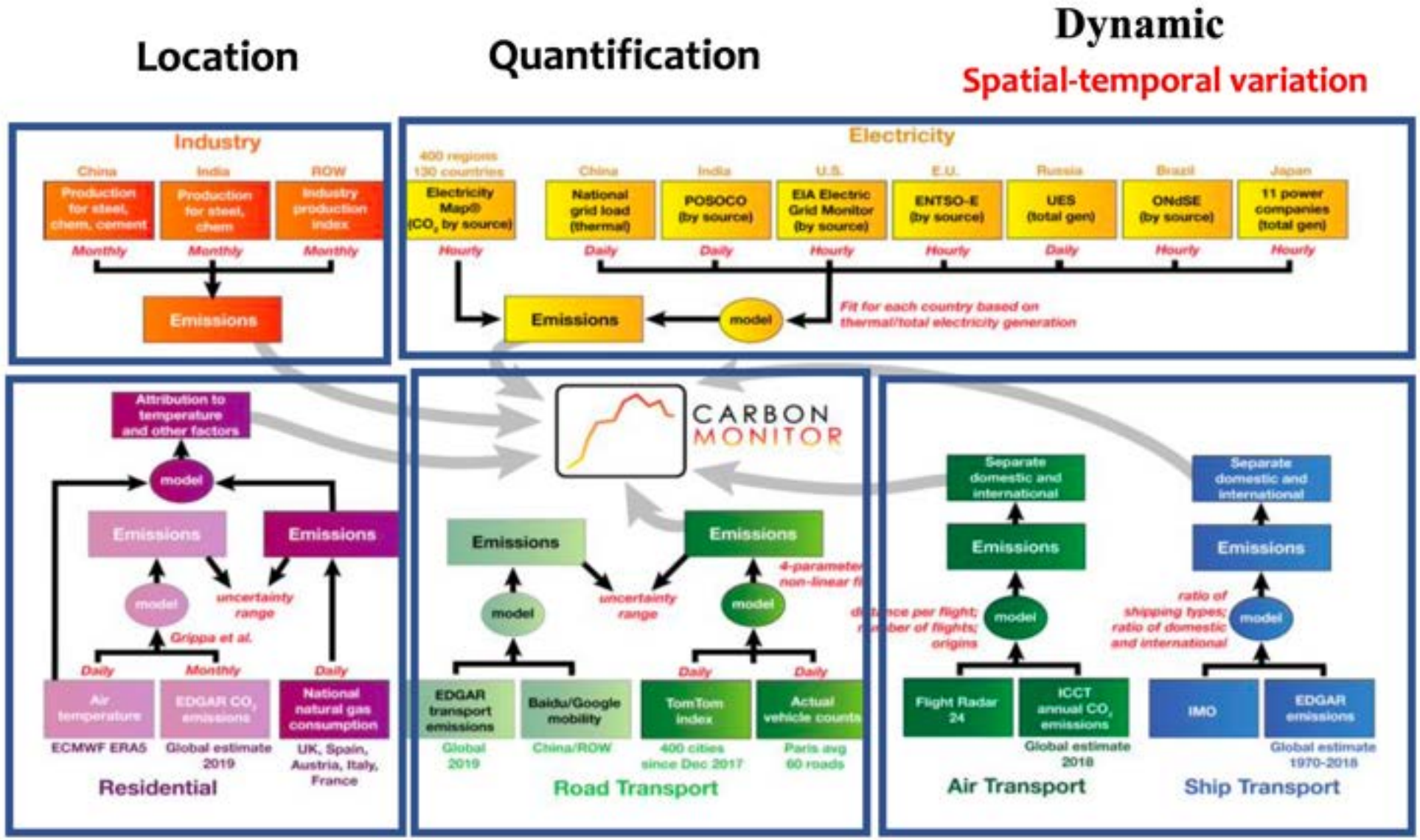
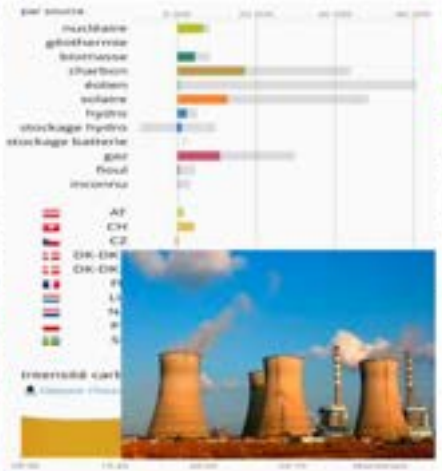
More than 20 young researchers

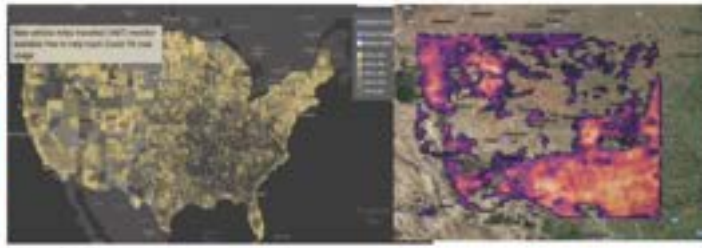
Our approach : consider emissions as the result of a complex human system



Collecting daily / hourly activity data related to CO_2 emissions in different sectors in each world region

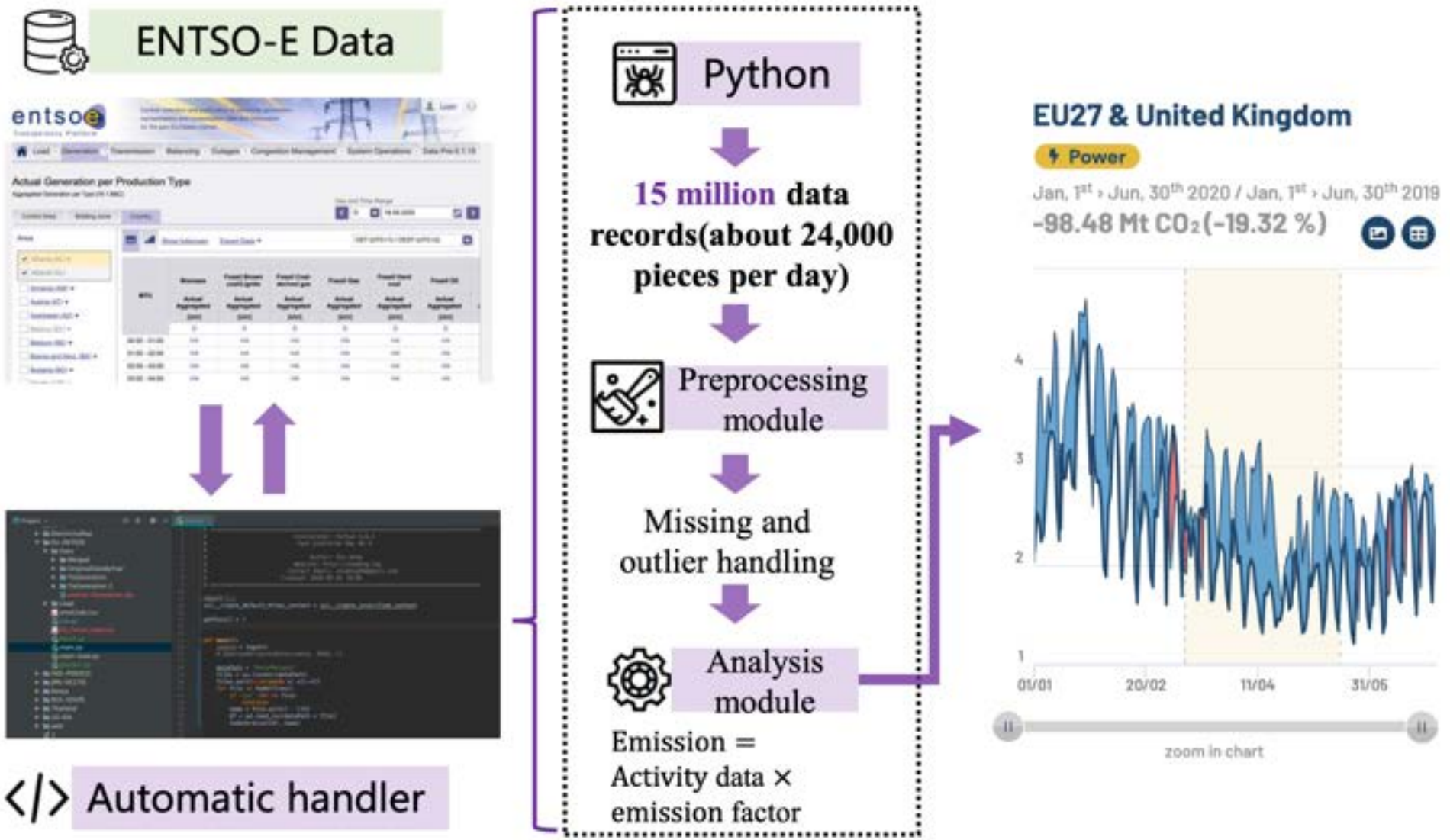
Natural gas





Thermal power generation

Example : Power generation: hourly/sub-hourly data for 31 countries



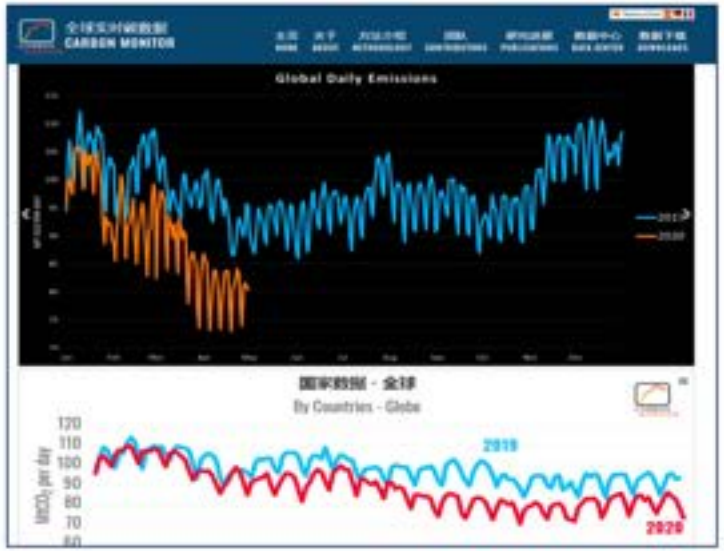
Carbon Monitor data & publications

Article | Open Access | Published: 14 October 2020

Near-real-time monitoring of global CO_2 emissions reveals the effects of the COVID-19 pandemic

Zhu Liu, Philippe Ciais, Zhu Deng, Ruixue Lei, Steven J. Davis, Sha Feng, Bo Zheng, Duo Cui, Xinyu Dou, Biqing Zhu, Rui Guo, Piyu Ke, Taochun Sun, Chenxi Lu, Pan He, Yuan Wang, Xu Yue, Yilong Wang, Yadong Lei, Hao Zhou, Zhaonan Cai, Yuhui Wu, Runtao Guo, Tingxuan Han, Jinjun Xue, Olivier Boucher, Eulalie Boucher, Frédéric Chevallier, Katsumasa Tanaka, Yimin Wei, Haiwang Zhong, Chongqing Kang, Ning Zhang, Bin Chen, Fengming Xi, Miaomiao Liu, François-Marie Bréon, Yonglong Lu, Qiang Zhang, Dabo Guan, Peng Gong, Daniel M. Kammen, Kebin He & Hans Joachim Schellnhuber -Show fewer

CARBON MONITOR



Daily data, graphics, methods freely available
https://carbonmonitor.org
https://carbonmonitor.org.cn

Zhu Liu, et al, *Nature Communications* 2020
Zhu Liu, *et al*, *Scientific Data* 2020

PROGRAMME OF THE EUROPEAN UNION
opernicus
ECMWF

30 peer reviewed publications / pre-prints since June 2020

More than 20 researchers working on different datasets weekly meetings …

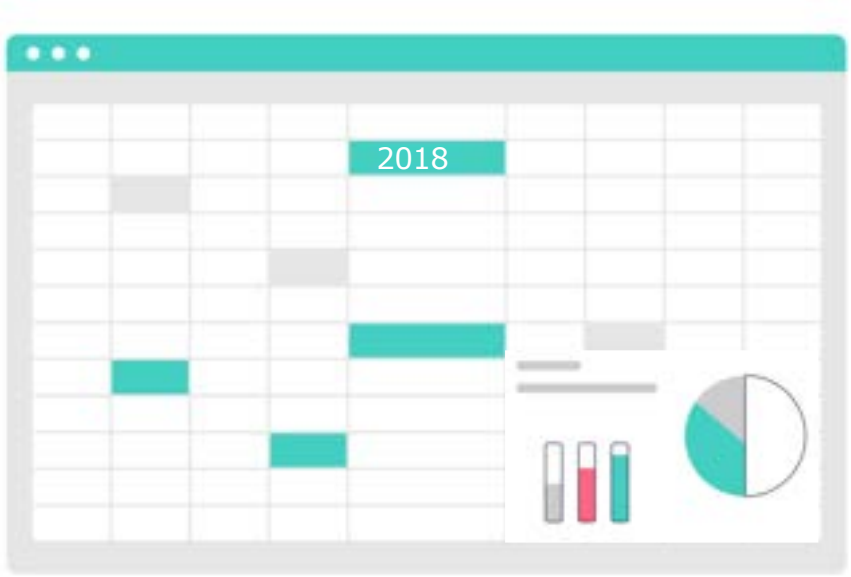
Supported in Europe by Copernicus CAMS CAMS51a

Products :

- **Global 36 countries + RoW**
- **China Province level**
- **US State level**
- **EU Country level**
- **Power ≠ sectors 130 countries**
- **Gridded maps of emissions**
- **Cities 1300 cities**

Carbon Monitor Cities

Should we face the challenge of the decade with an excel sheet ?



Time & accuracy gap due to costly and difficult data collection (1 to 4 years time lag)**.**

No mapping, targeting and GIS integration with city planning tool chain.

Not matching with MRV requirements for carbon credits and impact finance.

Imagine such a situation for health, mobility or waste management policies.

Carbon Monitor global gridded 10 km daily maps of emissions

GRACED is the fusion of daily national Carbon Monitor emissions, the GID large database of point sources, JRC EDGAR spatial activity patterns, TROPOPI NO_2 satellite data for changes of activity spatial patterns

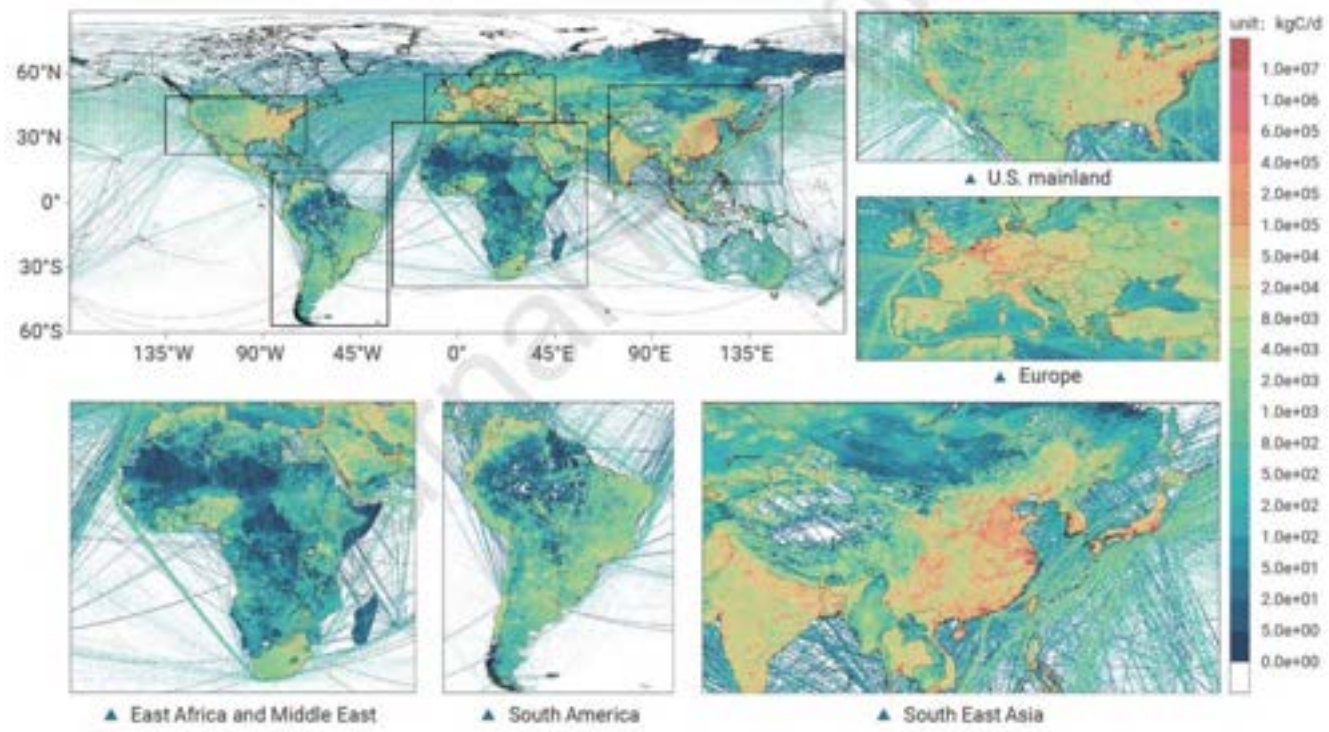
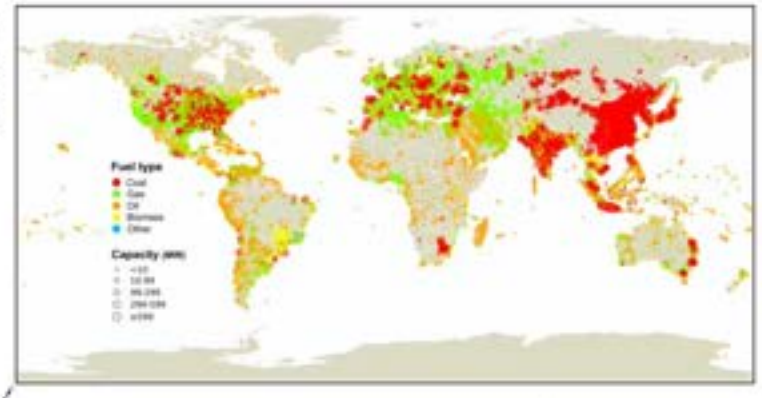


Figure 2. The fossil fuel and cement CO_2 emissions distributions of GRACED in 2020. The value is given in the unit of kg of carbon per day per cell.

Dou et al., *The Innovation*, 2021

Carbon Monitor Cities 1.0 - Workflow

More than half of the global CO_2 emissions in 2019 are estimated as point sources with accurate geographic coordinates.



- spatial patterns provided by GID to allocate the national-level emissions of Carbon Monitor to obtain the daily gridded emissions under GID's annual spatial patterns.
- monthly spatial patterns of EDGAR for further correction, to correct the previous daily gridded emission based

Carbon Monitor
A near-real-time daily dataset of global CO_2 emission at the national level

Spatializing Gridding

EDGAR v5.0 FT2019 | TROPOMI | GID

Gridded Carbon Monitor
GRACED

Step 2*

City-Level Disaggregation

Global Administrative Areas (GADM)

Functional Urban Areas (FUA)

Raw City-Level Data

Step 3

Outlier and Discontinuity Correction

Multi-Source Validation and Correction

CDP | Vulcan | CEADs

Carbon Monitor Cities
A near-real-time daily CO_2 emission dataset for global cities

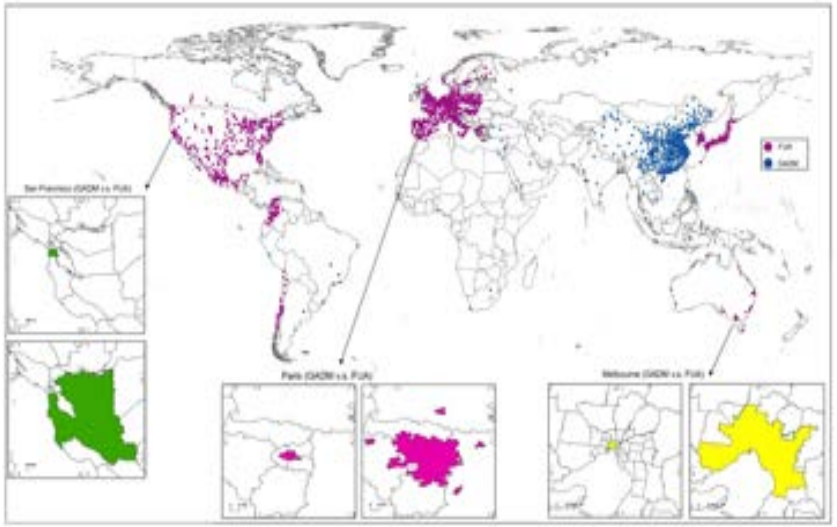
Da Huo et al. in prep.

*CM Gridded dataset (GRACED): Dou et al., 2021

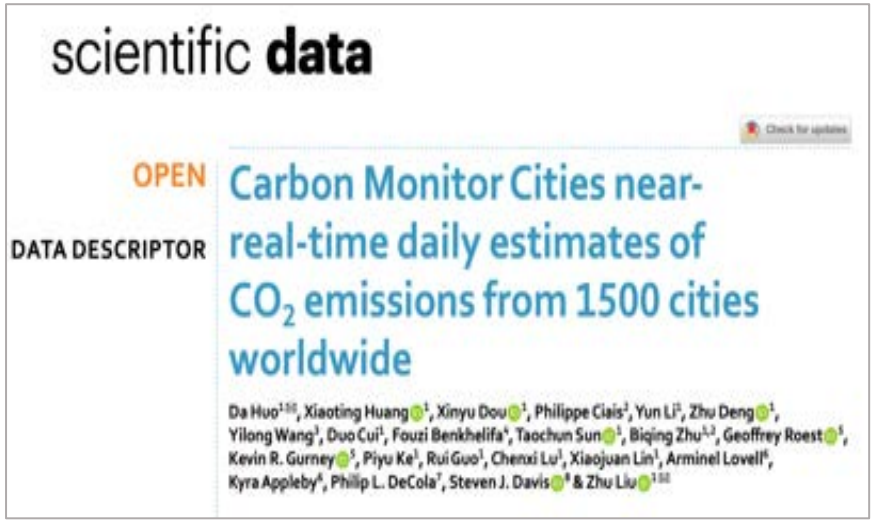
Carbon Monitor

Carbon Monitor Cities 1.0 - Coverage of 1300 cities

- Locations: Cities with available and accessible recent GHG emission inventories
- Coverage : 1500 cities
- Yet very few in Africa, Middle East and South Asia
- Update each 3 months
- Latency of 3 months
- Estimates on GADM & FUA areas



FUA: Functional Urban Area
GADM: Administrative Area

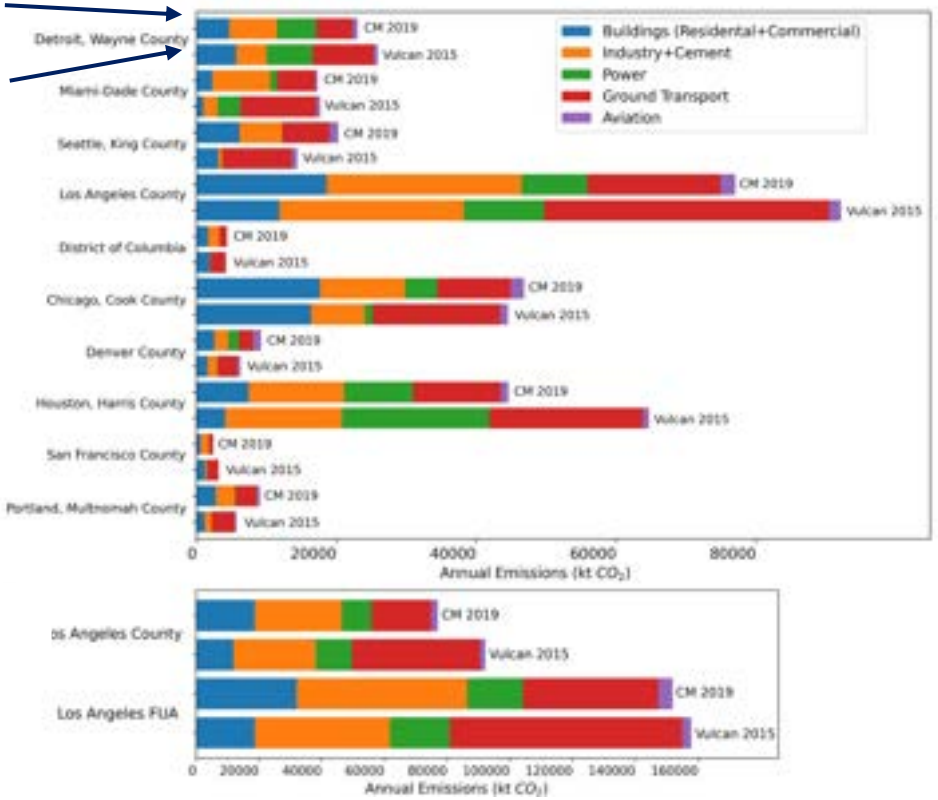


Evaluation against independent urban inventories

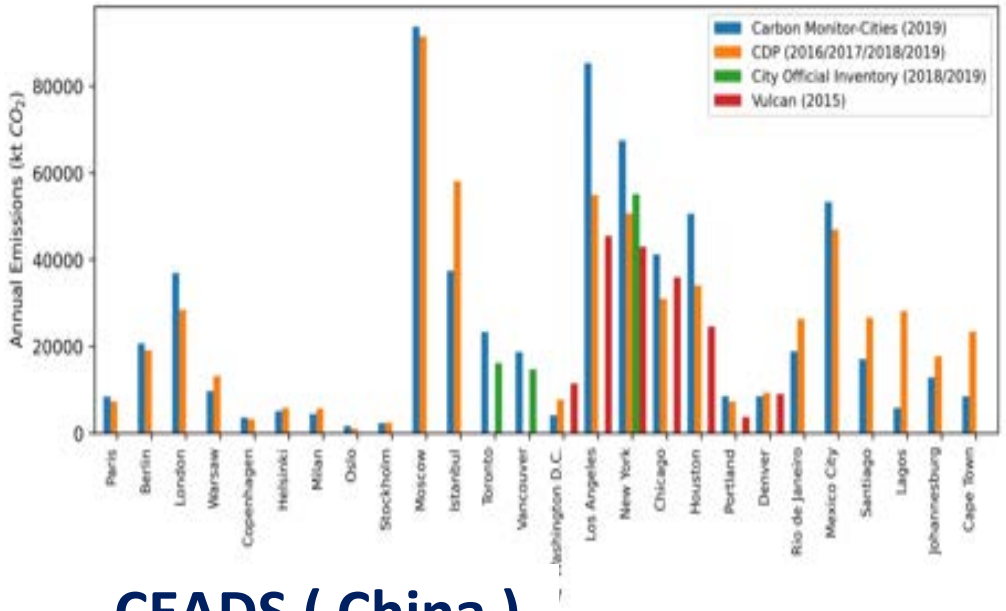
VULCAN (US, year 2015)

Carbon Monitor Cities 1.0

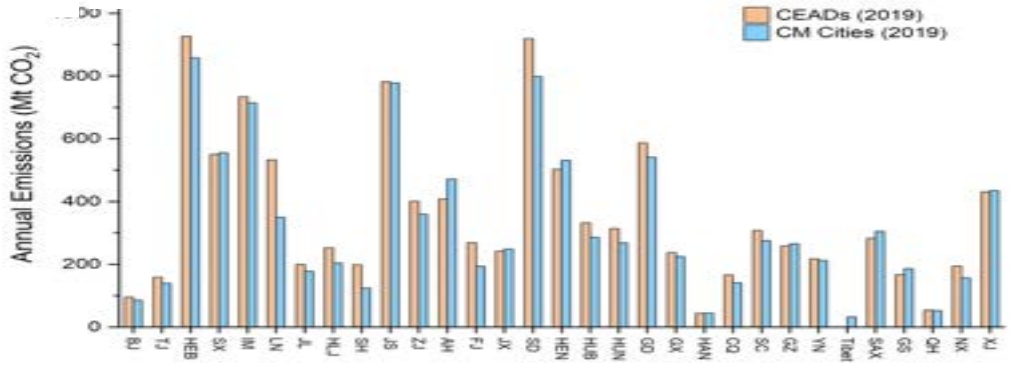
VULCAN



CDP and Cities reports (Globe)



CEADS (China)

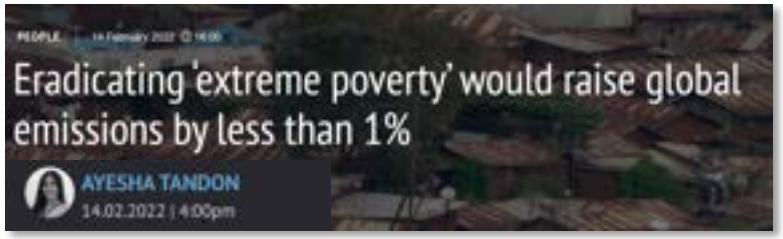


What's next ?
Carbon Monitor 2.0
High resolution near real time daily emissions for all cities

- Develop a global and universal NRT dataset of GHG emissions at high resolution (down to building / block / street level) with a nested approach:
  - **Inter-comparable methodology : Globe -> Country - > Region -> City -> Block**
  - **5 sectors (buildings, power, industry, ground transport, aviation)**
  - **Daily time series**
  - **Automated update with a 10 days latency**

- Focus on Global South Cities where data is scarce
  - **Downscaling with high resolution proxy data : building features / street traffic**
  - **New methods for cities with no data**
  - **Could be extended to combustion pollutants**
  - **Emission scenarios systems for urban planning and clean air policies**

Mumbai
https://www.mediapolisjournal.com/2019/11/the-mumbai-slum/



They are in the same country and the same city,

BUT WHO EMITS **MORE CO_2** ?

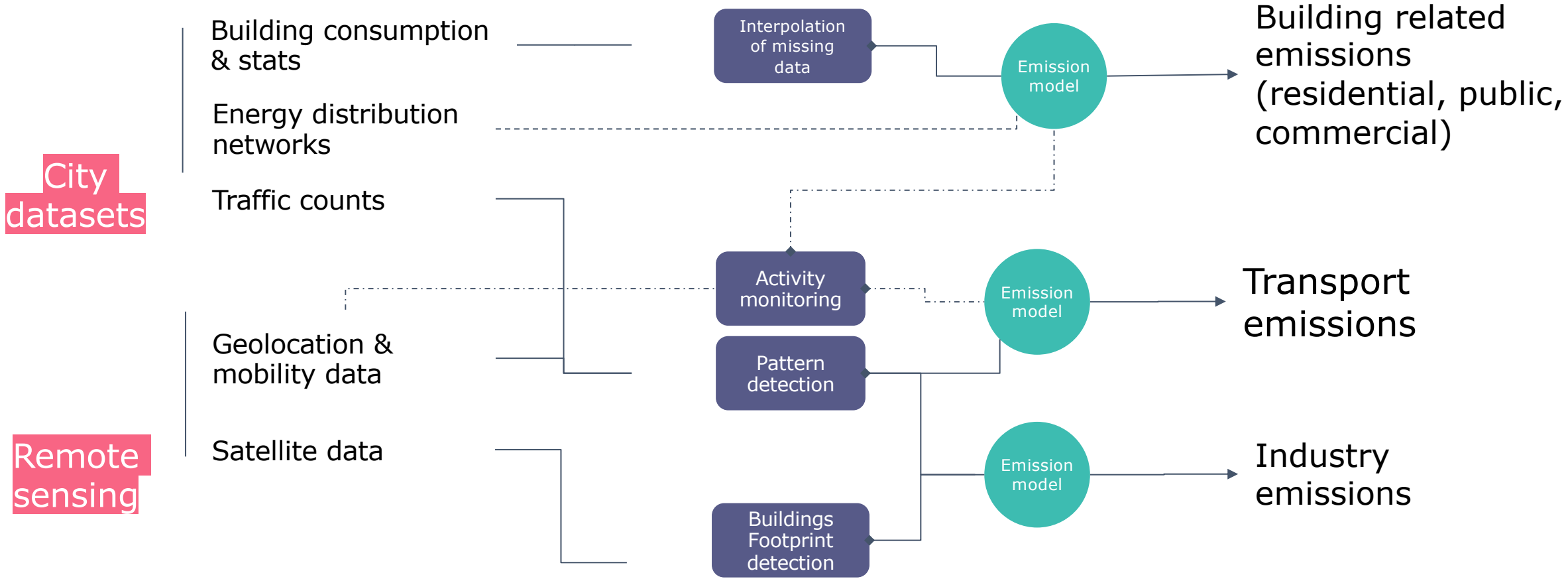
Johannesburg
https://unequalscenes.com/kya-sandsbloubosrand

City block emission patterns provide:

a. **Detailed spatial distribution** of CO_2 emissions.
b. **urban morphology** vs. **CO_2** emissions.
c. New data to support **mitigation strategy and policy.**
d. **Scenarios for impact of urban planning on emissions**

Carbon Monitor Cities 2.0
From City to building/street level

Going the last mile using AI



Challenges to derive NRT high-res CO_2 emissions

CO_2 Emission

= Σ Activity × Emission Factor

= Σ Population	×	**Activity Intensity**	×	**Emission Factor**
challenge 1: How to map city block-level population accurately?		**challenge 2: How to estimate activity in near-real-time ?**		**challenge 3: How to estimate emission factors for city blocks?**
Machine Learning		Satellite Images		Data Fusion
Predict **building morphology** (height and type)		Use **night-time light, temperature, pollutants imagery**, …		Develop a building level emission intensity index -> **poverty/development**

Regional features of buildings

Level 0: Data Fusion

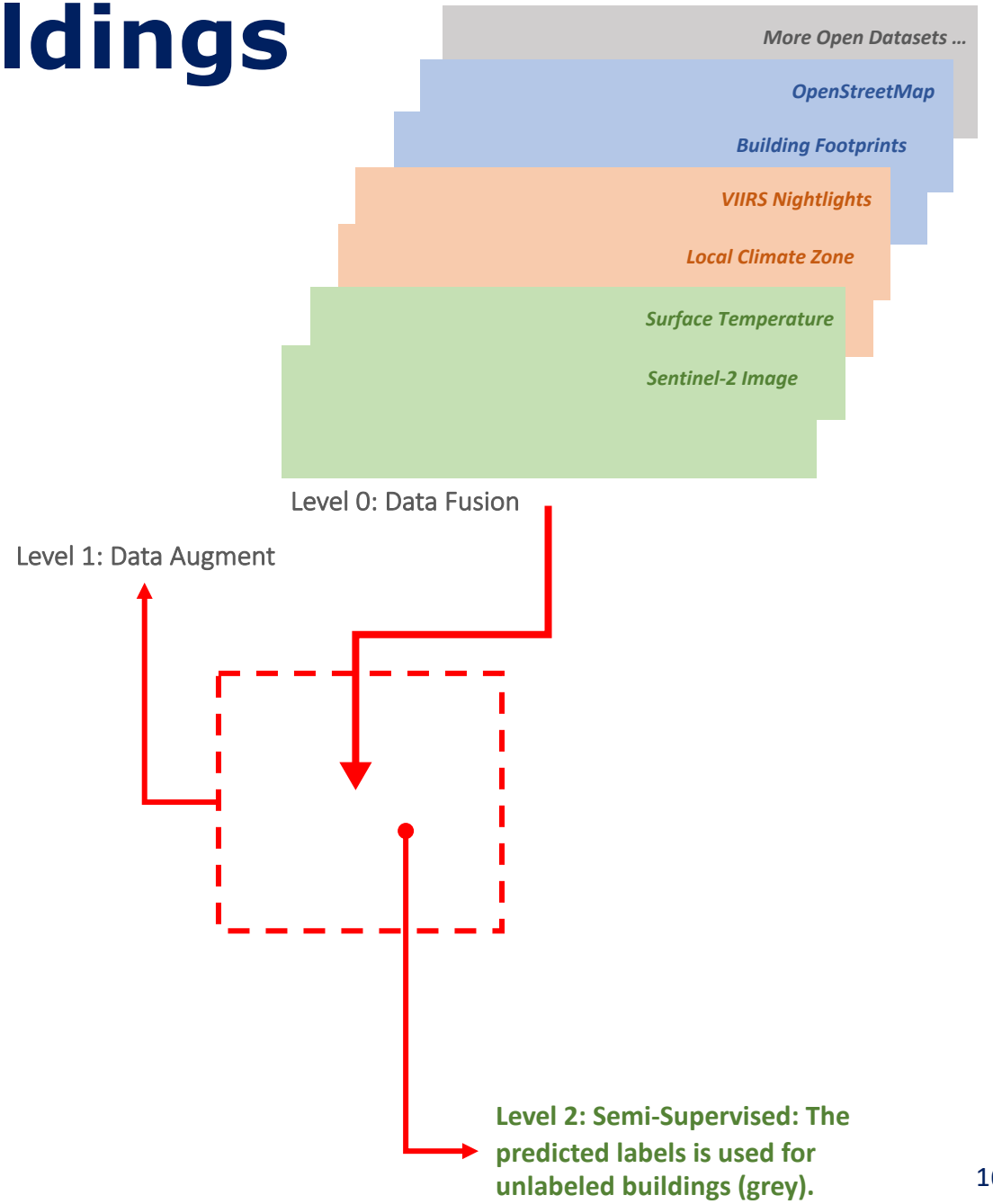
1) Merge polygons
2) Create a training set by collecting building features from various datasets

Level 1: Data Augmentation

1) Create regional level features
2) Extract extra information from regional properties (such as roads)
3) Reduce the data noise for building level features

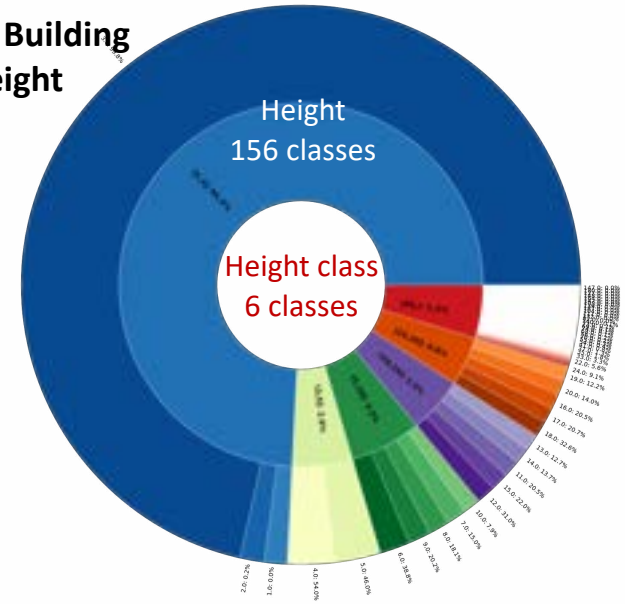
Level 2: Semi-Supervised Learning

1) After model is trained, we can estimate the values for unlabeled buildings, then update regional features
2) With semi-supervised learning, the model gets more precise regional features



Buildings classification

a) Building height

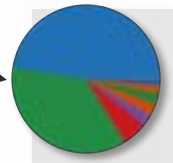


b) Building Type

True pie plot for label number

Type:
156 classes

Height class:
[1-3]: 91.5%
(3-5]: 2.0%
(5-10]: 3.3%
(10-15]: 1.5%
(15-20]: 0.6%
>20: 1.1%



Type level 0:
92 classes

Type level 2:
Residential:47.5%
Agricultural: 36.3%
Industrial: 5.5%
Religious: 2.5%
Others: 2.5%
Civic: 2.5%
Commercial: 1.7%
Transportation: 1.3%
Sports: 0.1%

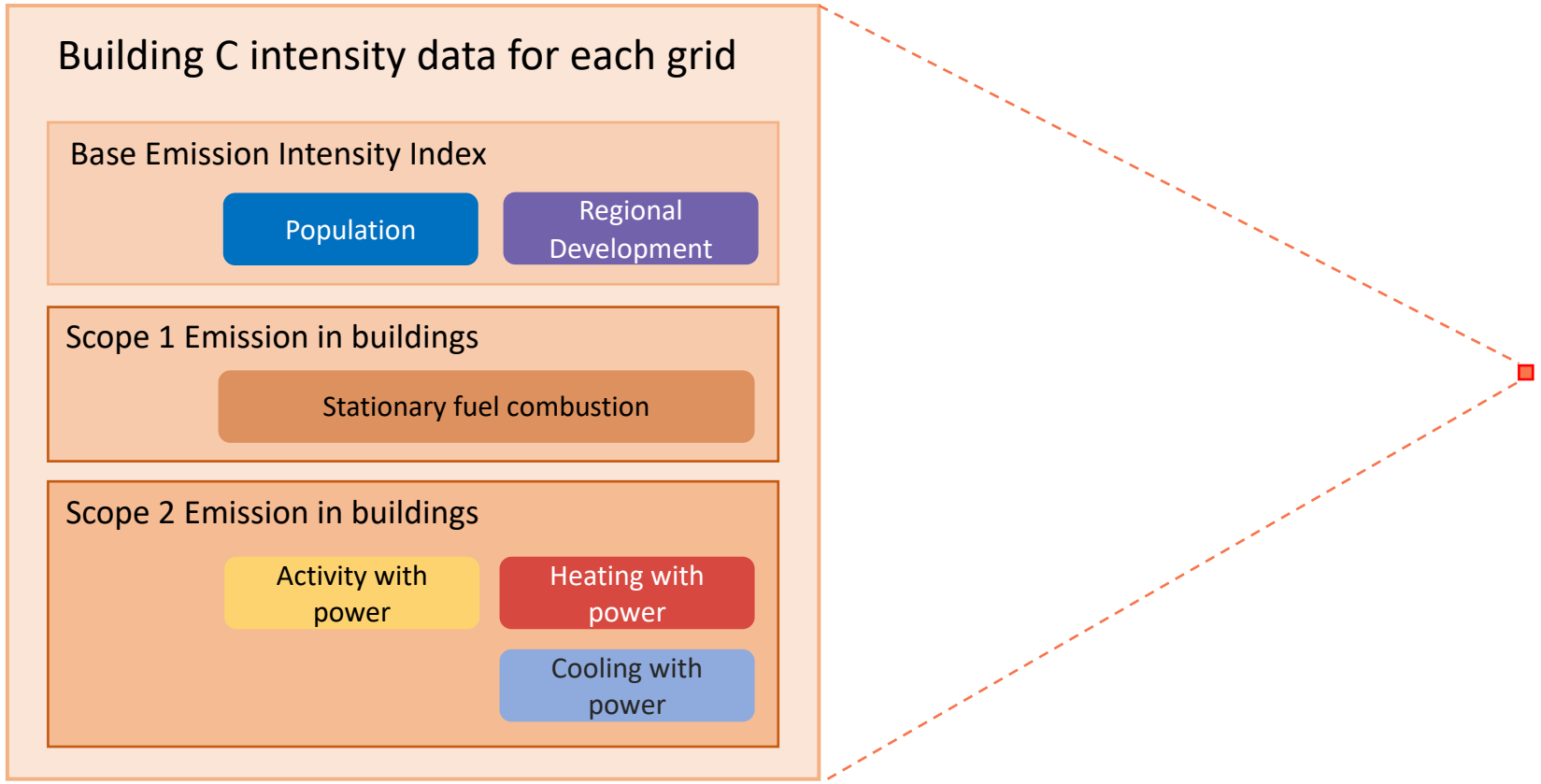
Highly **imbalanced** and **multiple-classes classification** is difficult.

Results : first high resolution NRT Emission maps

+ Buildings Carbon Intensity Index

Evaluates the potential CO_2 emission intensity for a particular building / timestamp

Example for Greater Cairo, Egypt

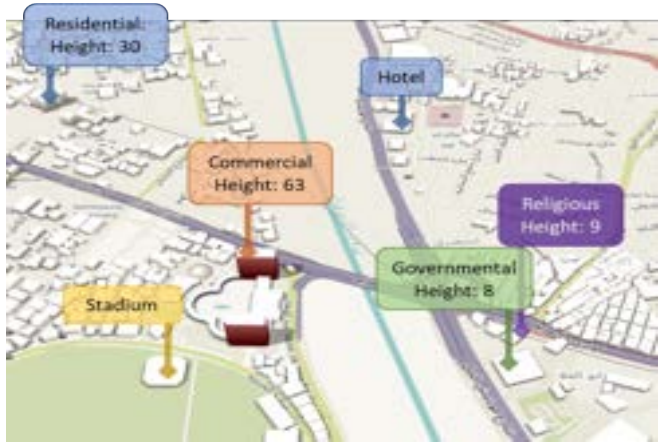


Prototype for 500 m spatial resolution: https://bigcarbon-viz.w3spaces.com/

Regions and Pilot cities

Plans to expand it to 100+ cities in India & 100+ cities in China in 2024
Extend to CO, NOx, BC

Labeled (OpenStreetMap, OSM building)

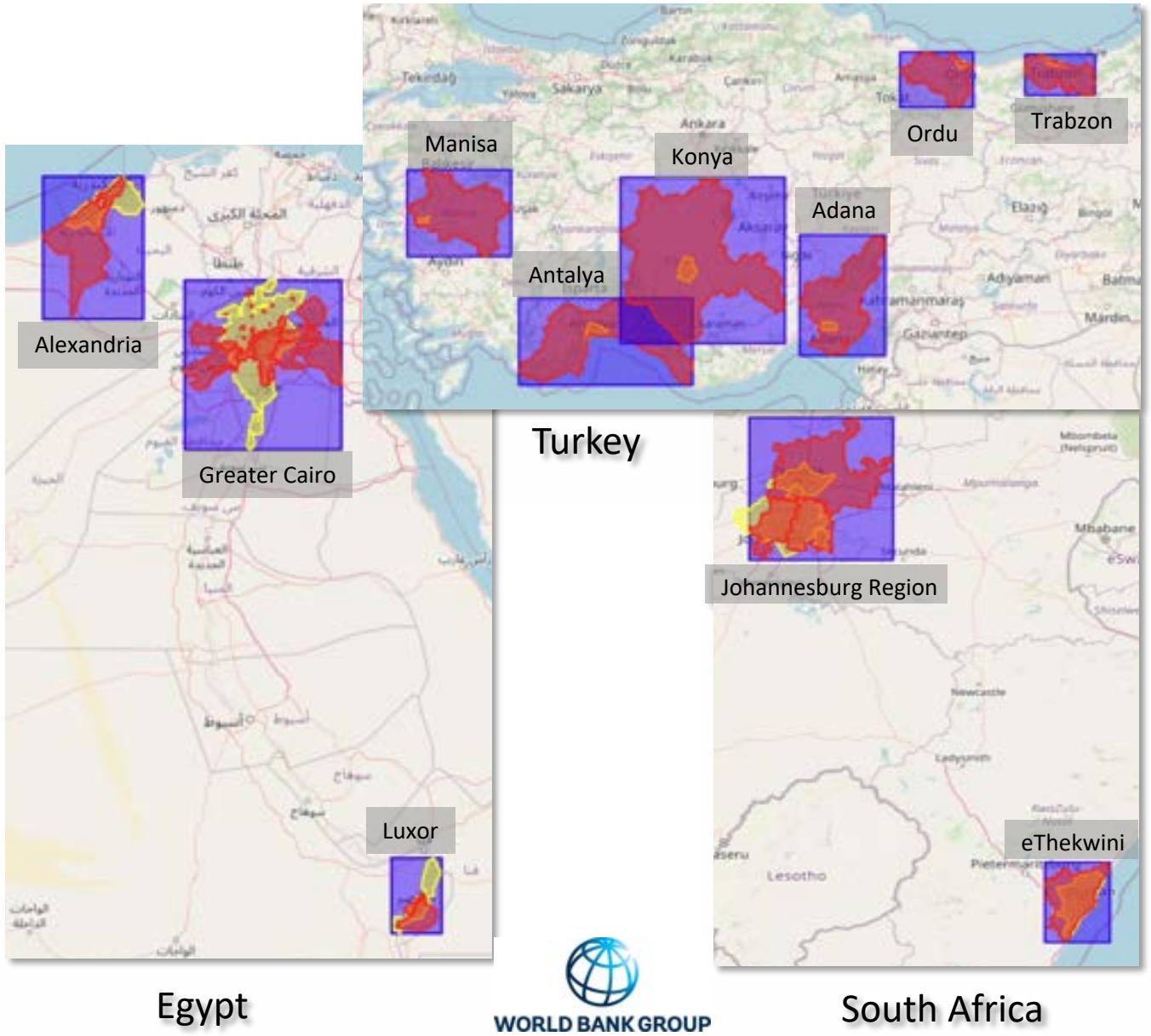


0.99 M data

Unlabeled (Microsoft Building Footprints)

9.2 M data

Polygons recognized by ML



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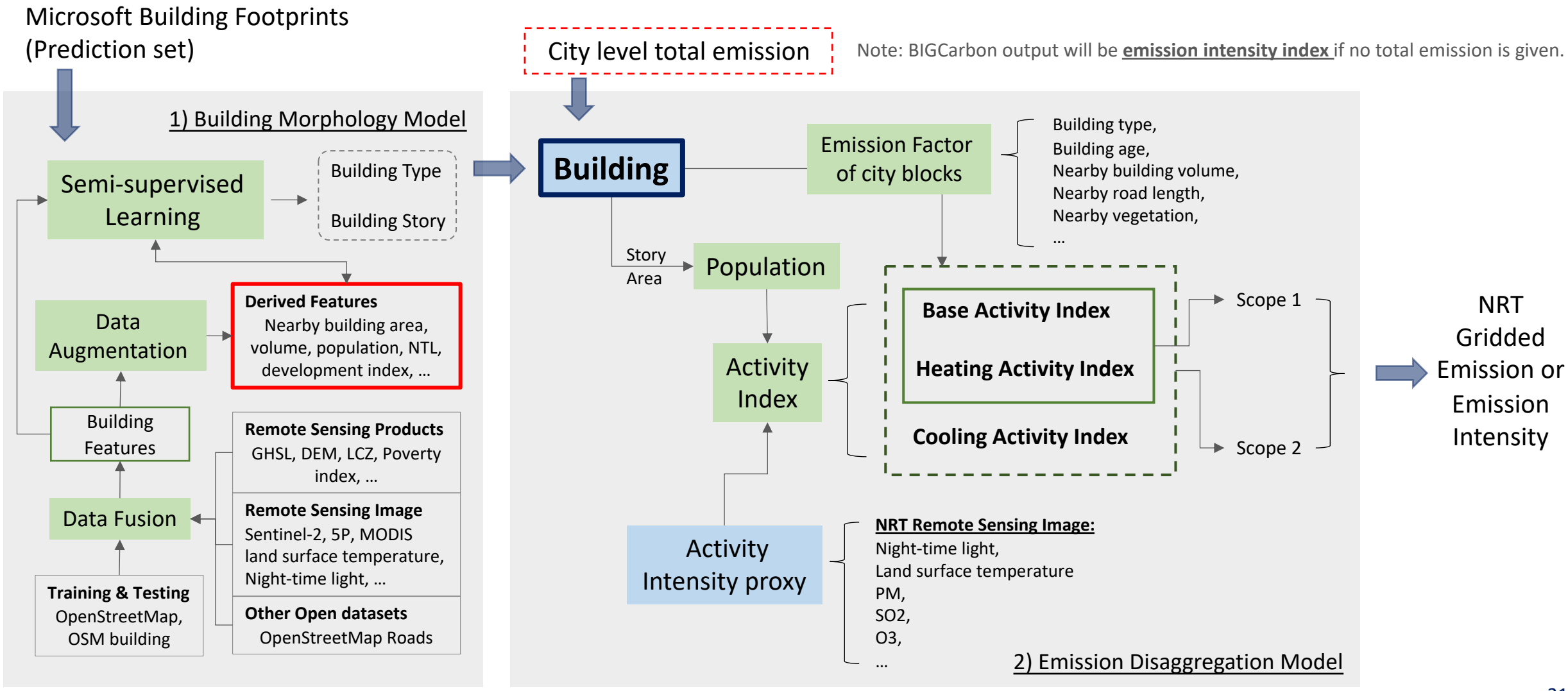
Thank you for your attention

We’ve been steering by looking in the rearview.
Advances (spurred by COVID) offer decision makers timely feedback to support more agile and adaptive management of urban carbon emissions.

Framework

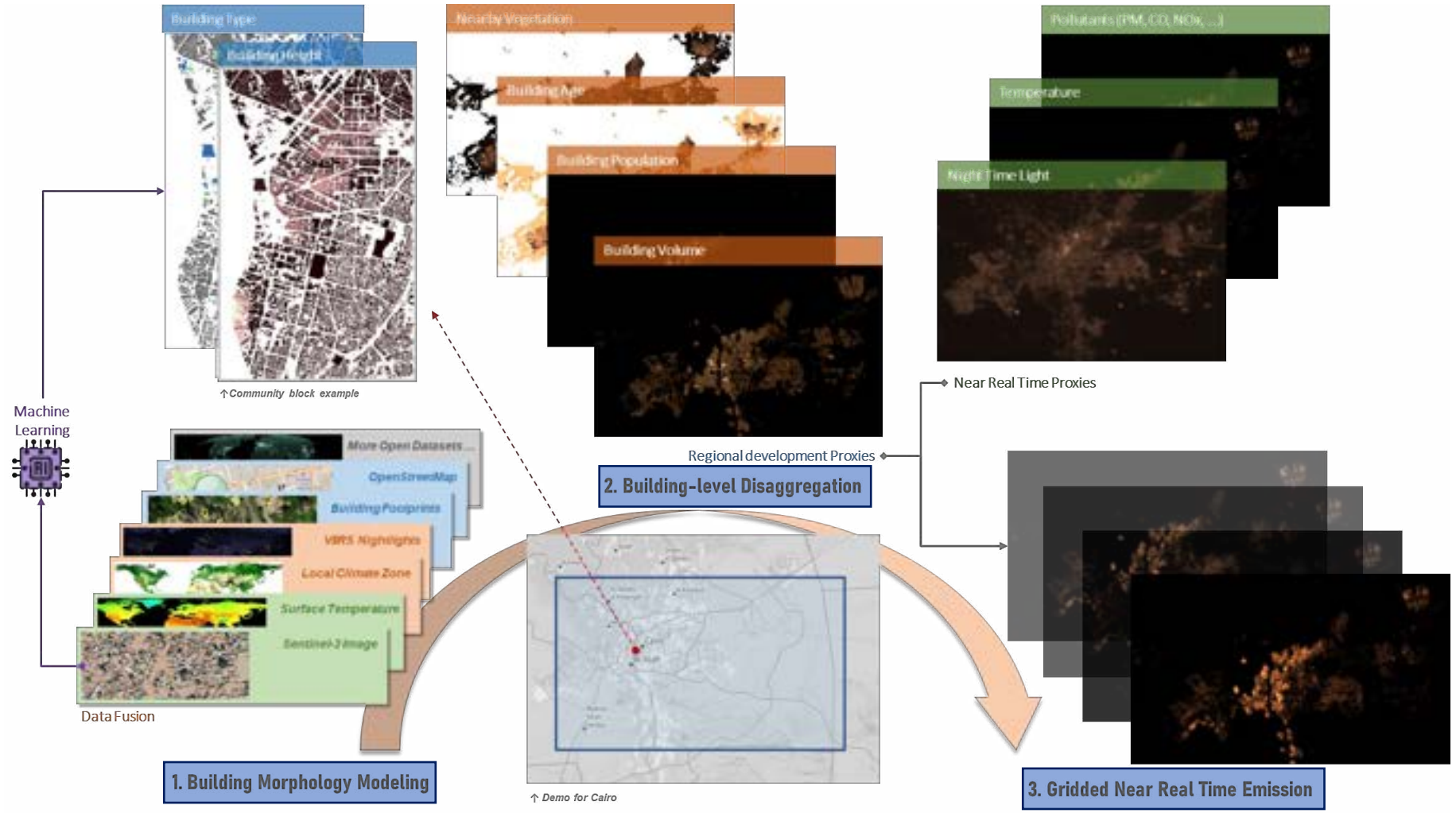
{ Building Integral Gridded Carbon Emission Disaggregation Model }



Carbon Monitor Cities 2.0

From **Building Features**, Satellite Image, Machine Learning
To **Fine Gridded** CO_2 Emissions Map in **Near-real Time**

Building Integral Gridded Carbon Emission Disaggregation Model



Terminology

City block

A fixed size of grid, e.g., 500 m× 500 m

Building Morphology

Building story number and type