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CoCO2 Prototype system for a Copernicus CO_2 service

CO2 Monitoring and Verification *Support*

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CO2M Roadmap Workshop, 24 October 2022

Are our (and others) estimates of GHG emissions 'correct'?

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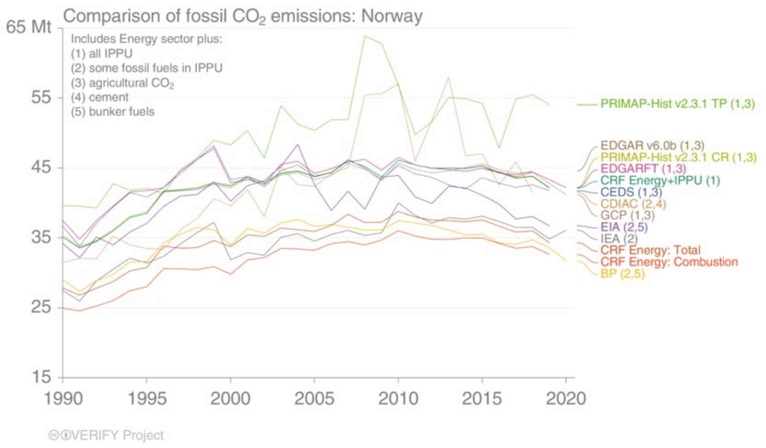
Quality Assurance, Quality Control, and Verification

- **Quality Assurance** (QA) is a planned system of review procedures conducted by personnel not directly involved…
- **Quality Control** (QC) is a system of routine technical activities to assess and maintain the quality of the inventory…
- **Verification** refers to the collection of activities and procedures … that can help to establish [an emission inventories] reliability …
  - Bottom-up: Inventory-based approaches
  - Top-down: Observation-based approaches

Bottom-up *inventory-based* verification



- A detailed comparison of bottom-up inventories
  - “Bottom-up”: Activity Data * Emission Factor (generally)
  - A *process* to understand *why* inventories differ…
- This is relatively cheap and should be done more often!
  - More eyes spot problems (we *all* make mistakes)
- And we find mistakes…
  - The EEA (EU) had errors in their uncertainty estimates (now corrected)
  - The EIA had errors in their oil estimates (now corrected)
  - Problems identified in major data products CDIAC, EDGAR, IEA, …
  - And yes, Norway has made mistakes in its inventories too

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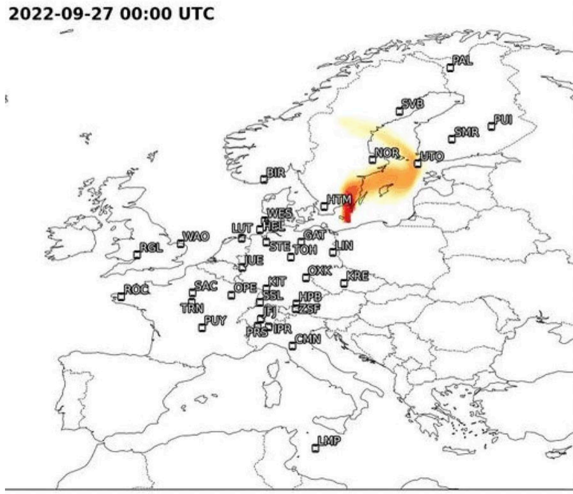

Top-down *observation-based* verification

- Not yet operational, but has had some successes
  - China had a “drop” in coal use ~2000 (NO_x used to show not true)
  - HFC underreporting has been identified (China, Italy, etc)
  - Nordstream CH_4 ‘leaks’ a nice example (strong, isolated signal)
- Quite complex
  - Highly resolved emission inventories needed (time and space)
  - A range of observations are needed (ground-based, satellites, etc)
  - A model is needed (trace air flows and atmospheric chemistry)
- CO_2 Monitoring and Verification Support (CO2MVS)
  - Because of the complexity, tools are envisaged to help users…

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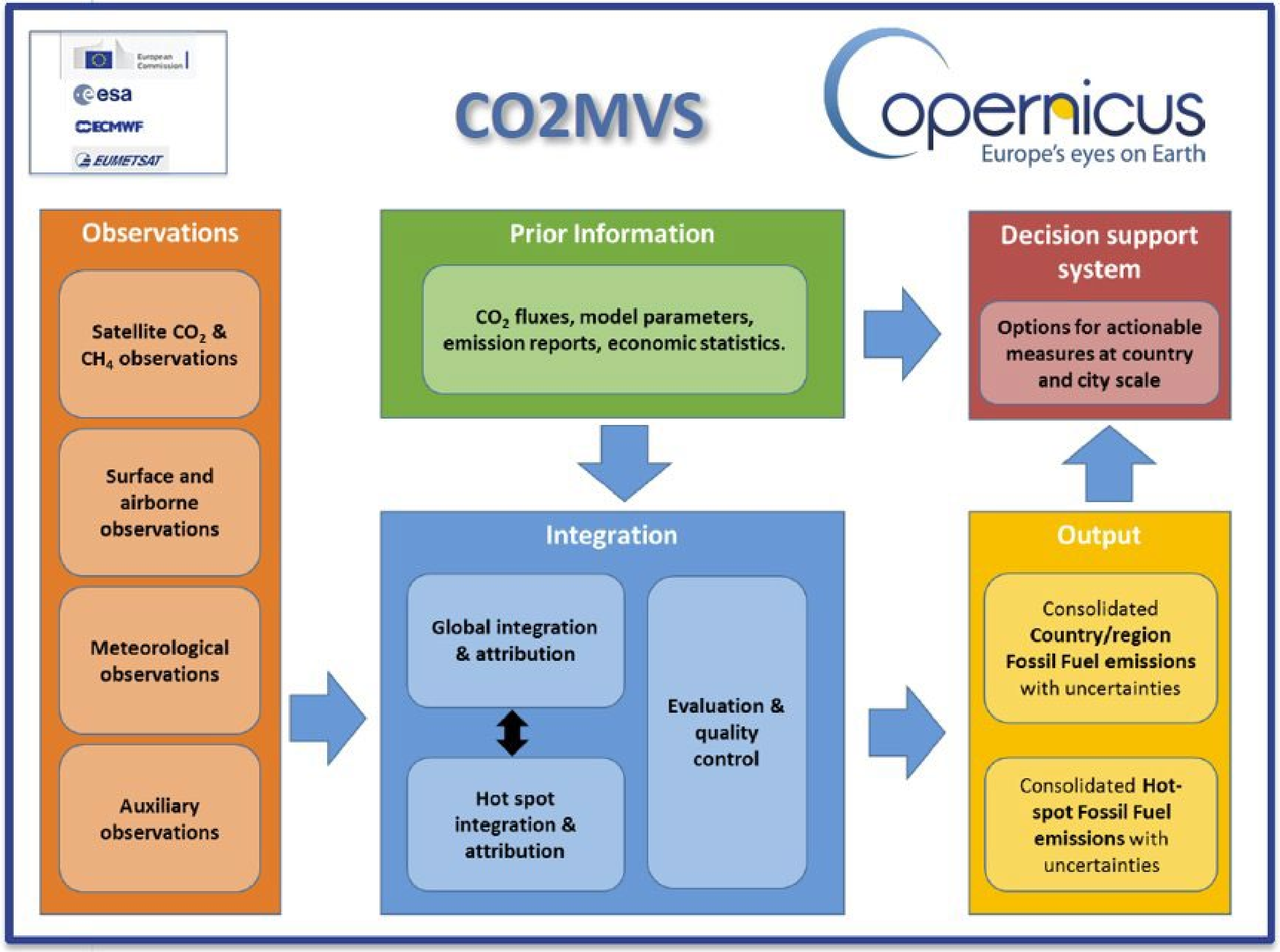
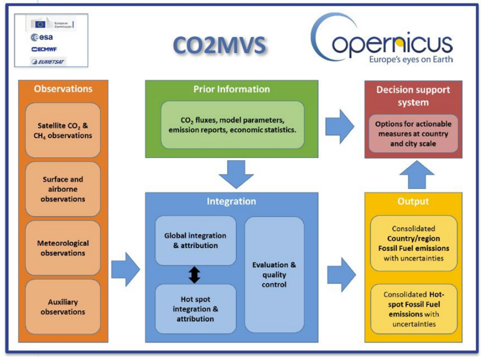
CO_2 Monitoring and Verification Support

A range of observations are needed (for a range of reasons), they are linked to a model (integration) and prior information on emissions, to give new estimates of emissions (in space and time). But, how to understand the output?



Decision Support System



- How to integrate top-down and bottom-up information?
  - Initially will focus on how to present data in a useable format (graphics)
  - Eventually become more operational
  - Different users will have different needs
- Managing expectations
  - What can and can't CO2MVS offer?
- Lots of issues arise quickly:
  - What is the data? What system boundary? What definition? What uncertainty? Variability? Clouds? Bias? Etc…
  - How to get this necessary information to users to truly give them support?

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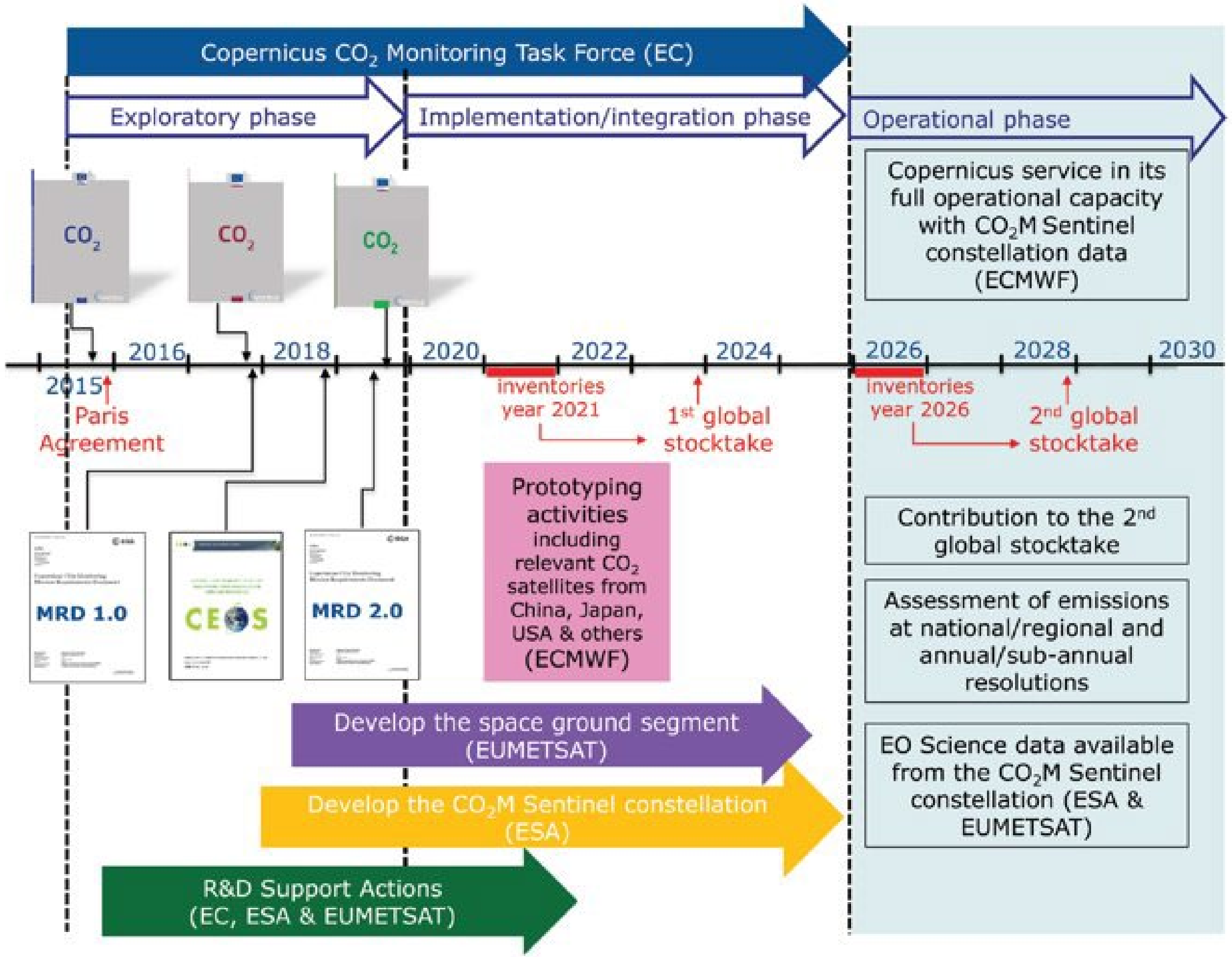
When will all this happen?

It is a long process, with many science projects continuing, to make the CO2MVS “operational” (2025+)

Norway involved in CHE (finished), VERIFY (finished), CoCO2 (ongoing), EYE-CLIMA (from January), …



Who is doing this already? (at the national level)

- Verification systems in place in UNFCCC reporting:
  - Switzerland (CH_4, N_2O, F-gases)
  - United Kingdom (CH_4, N_2O, F-gases)
  - Australia (CH_4, N_2O, F-gases)
  - United States (F-gases)
- Advantages and disadvantages
  - F-gas: No natural sources, a few observations go a long way
  - CH_4, N_2O: Very uncertain, only a decent observation network needed sufficient
  - CO_2 LULUCF: Inventory is uncertain, & processes are highly complex
  - CO_2 FFI: Uncertainty is low (mass balance), inventory is hard to beat!

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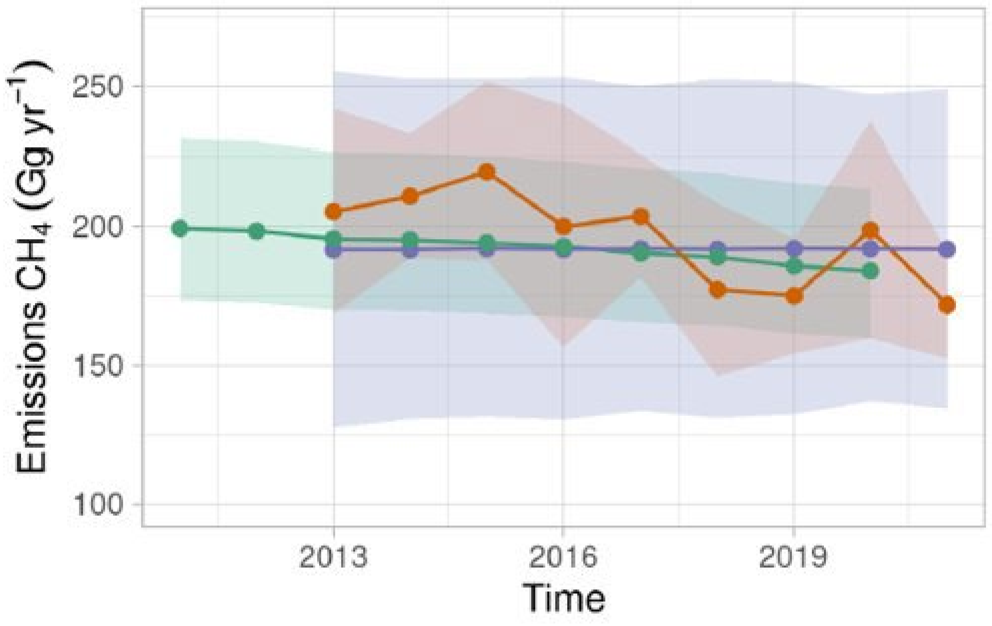
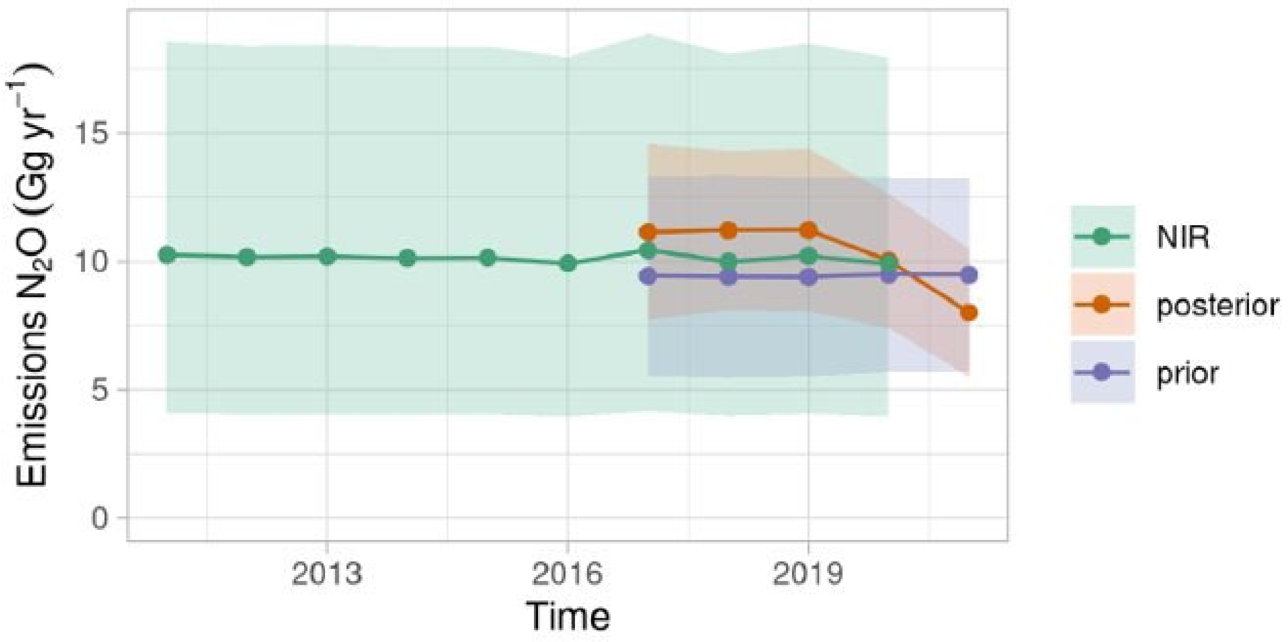
Switzerland

Most important is how the prior uncertainties changes relate to the posterior (how constrained is the model?)
Trend detection may also be relevant. The National Inventory Report (NIR) is the reference comparison.

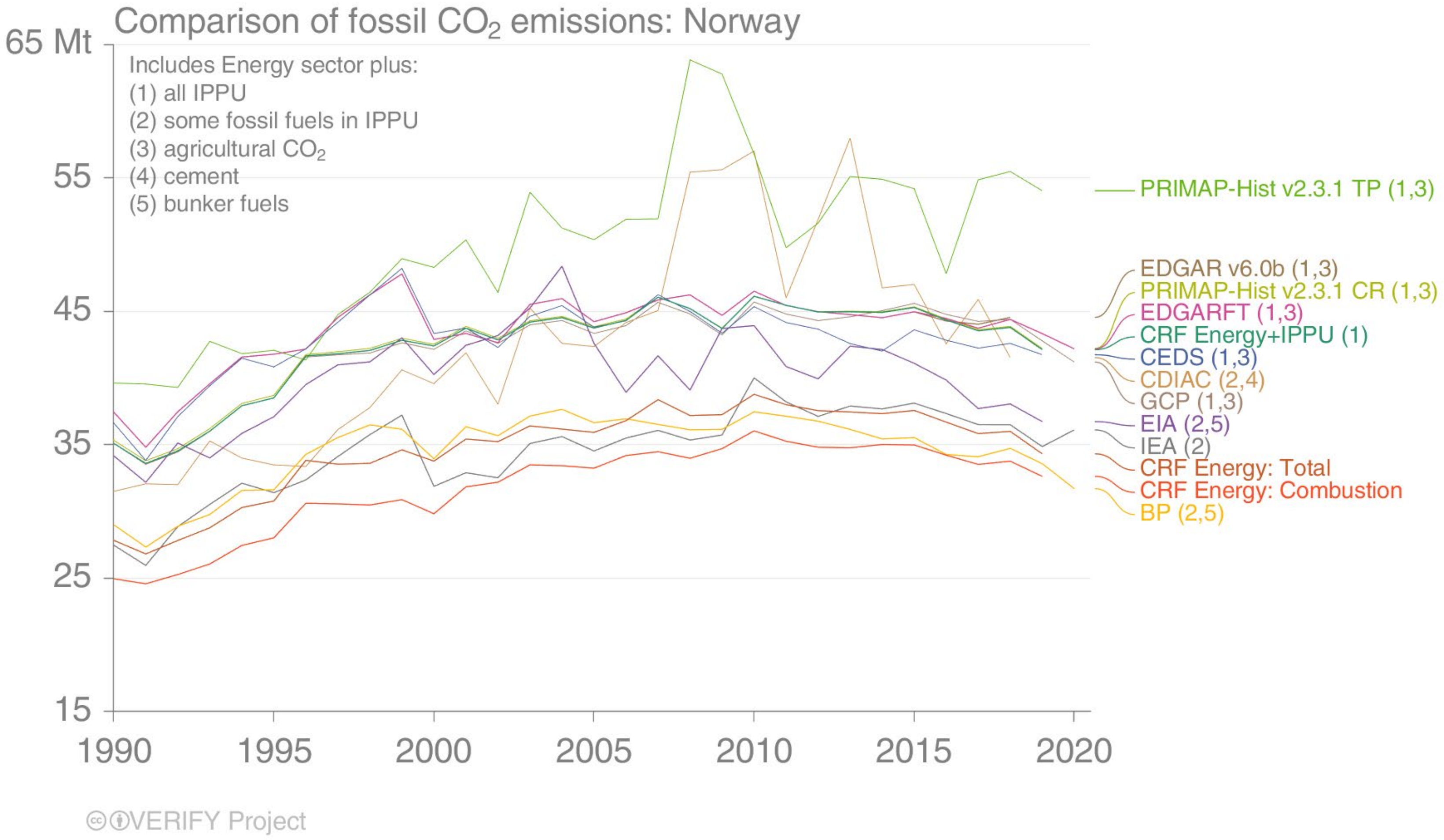




Some Norwegian examples

Norway's fossil CO_2 emissions

Estimates vary widely between datasets, but many differences are due to different system boundaries (definitions)



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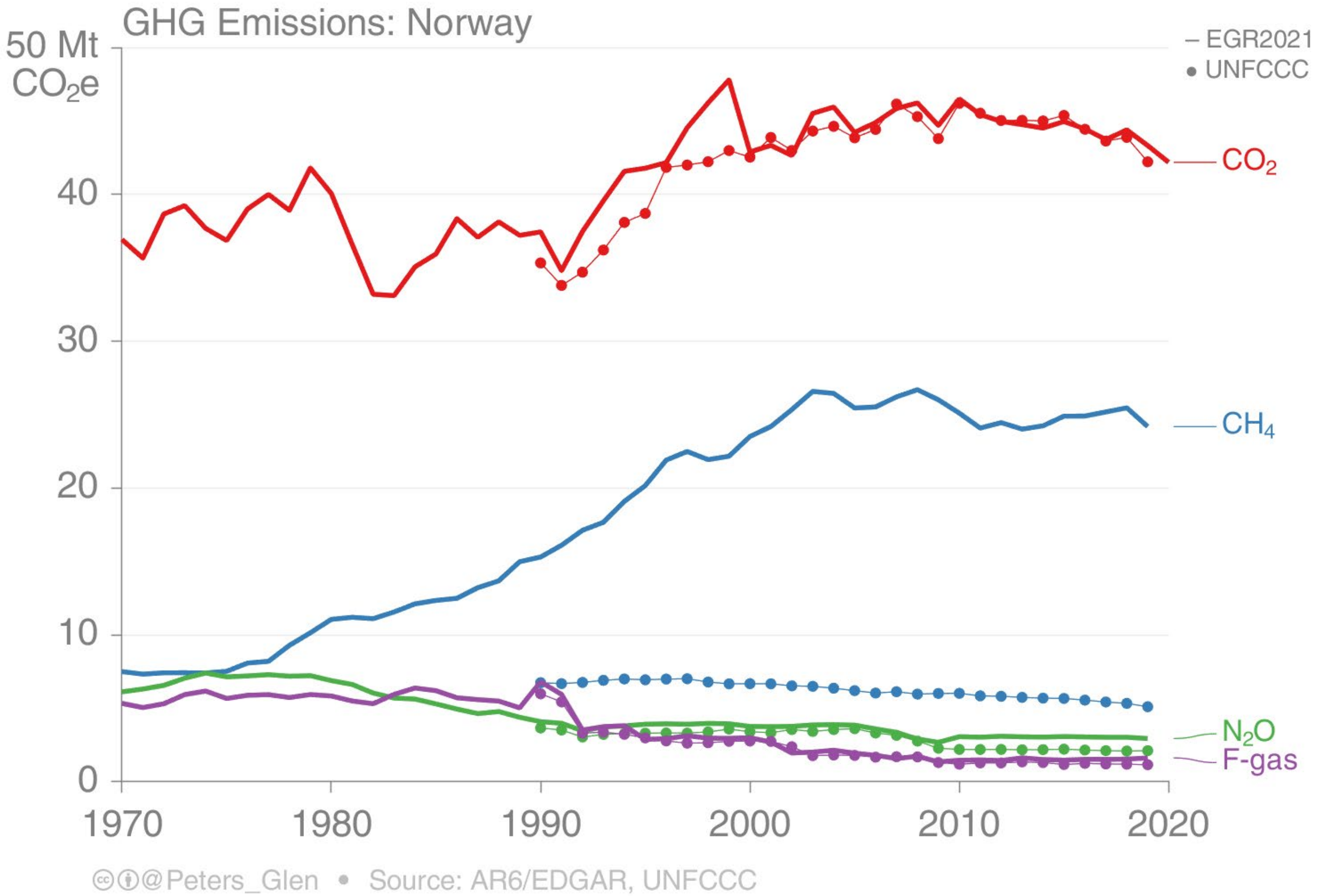
Norway’s CH_4 emissions

Many researchers use EDGAR, as it is global, gridded, harmonised, etc. But, how does it compare to the UNFCCC?
EDGAR has used global assumptions for fugitive CH_4 and that turns out to be incorrect for most of the Nordics



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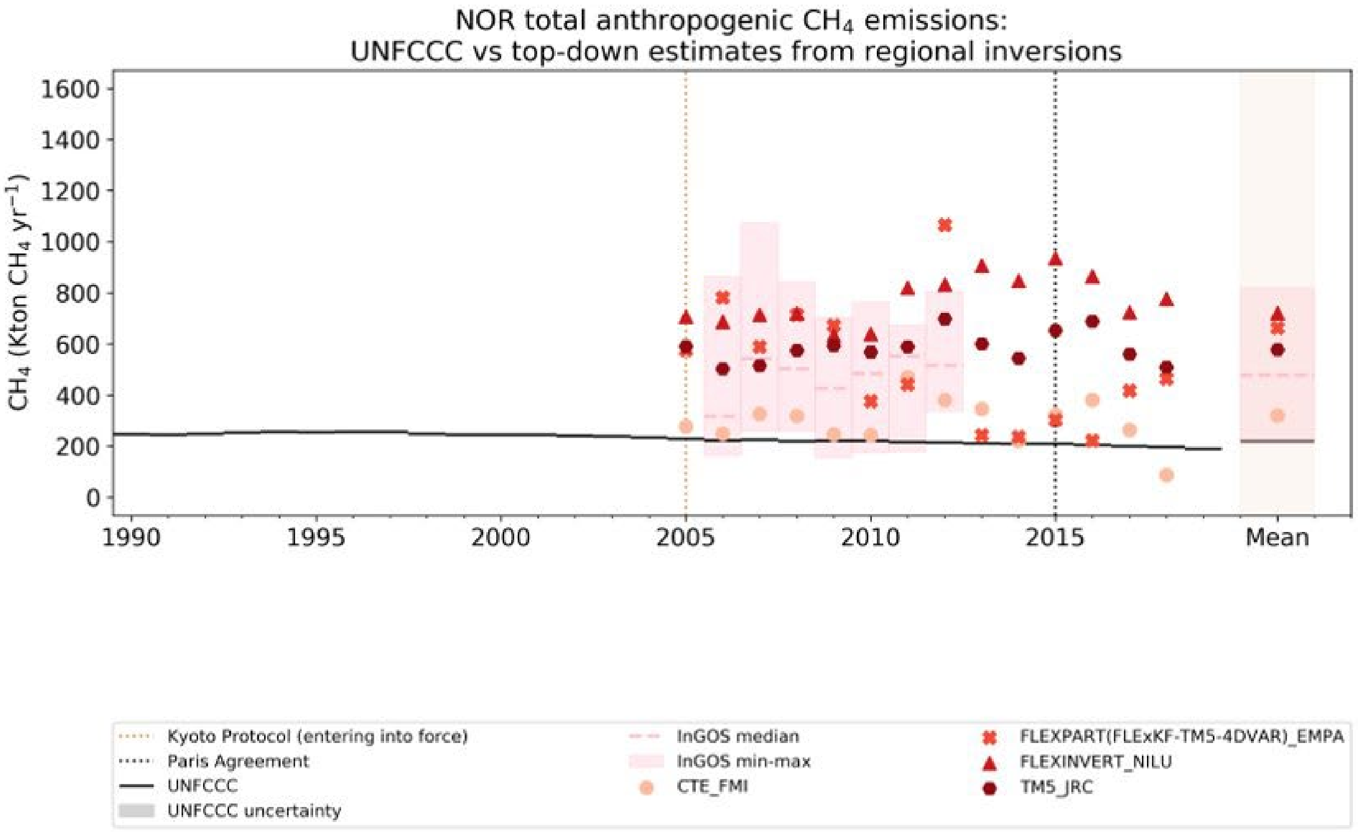
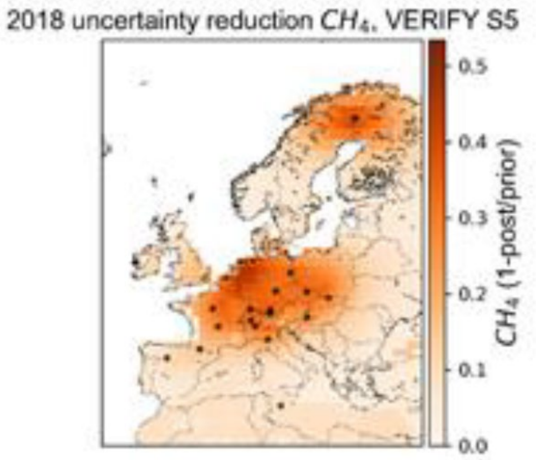
Source: UNFCCC, EDGAR

Top-down CH_4 estimates for Norway (poorly constrained)

Top-down estimates are generally much higher for Norway, *but this should not be overinterpreted…*

Most inversions use EDGAR, if observations are insufficient constrains, then posterior similar to prior estimates





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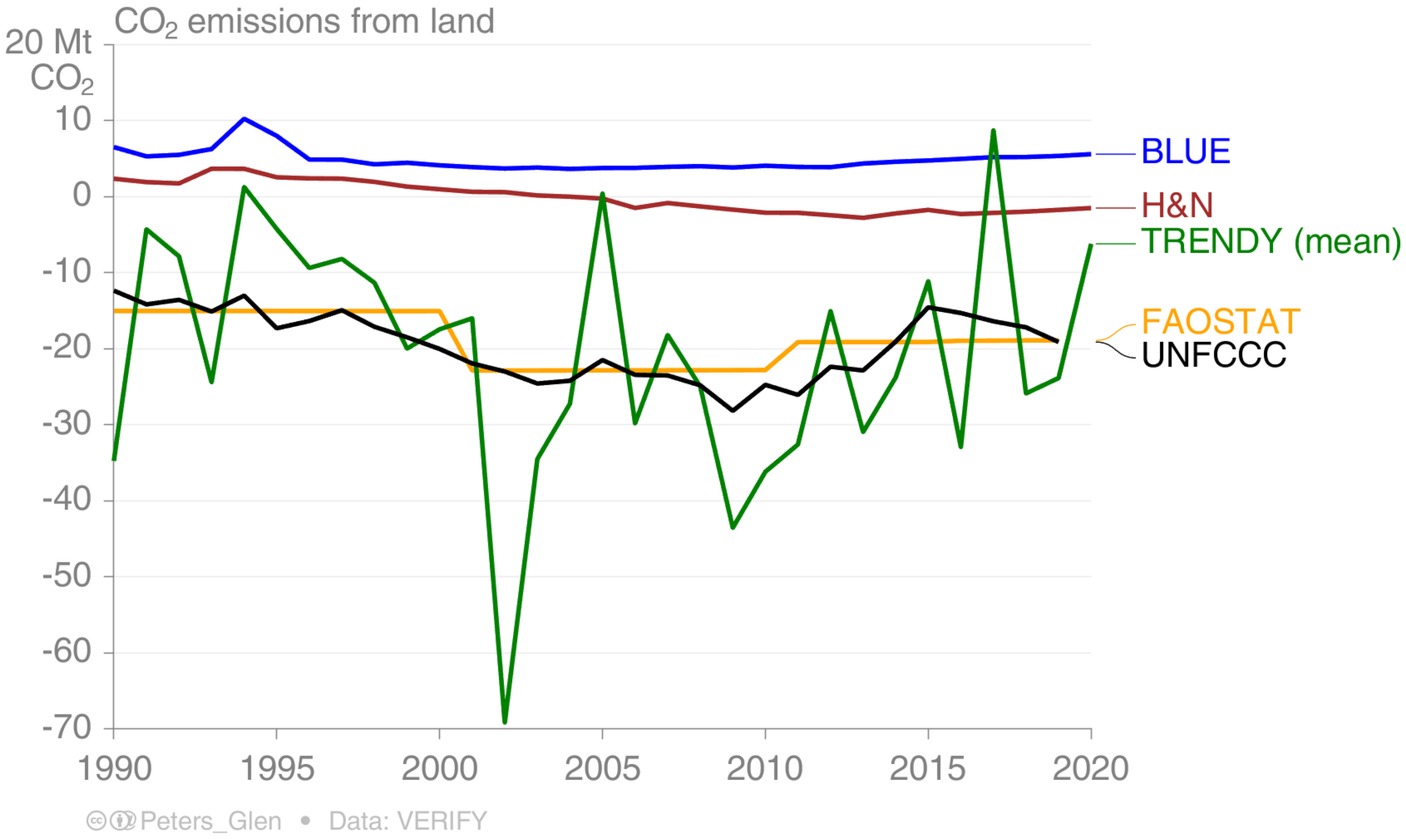
LULUCF – A much harder exercise…

The two 'bookkeeping models' (BLUE, H&N) differ to UNFCCC because of *system boundaries*.
TRENDY is an ensemble of land-surface models, process-based models & therefore including variability



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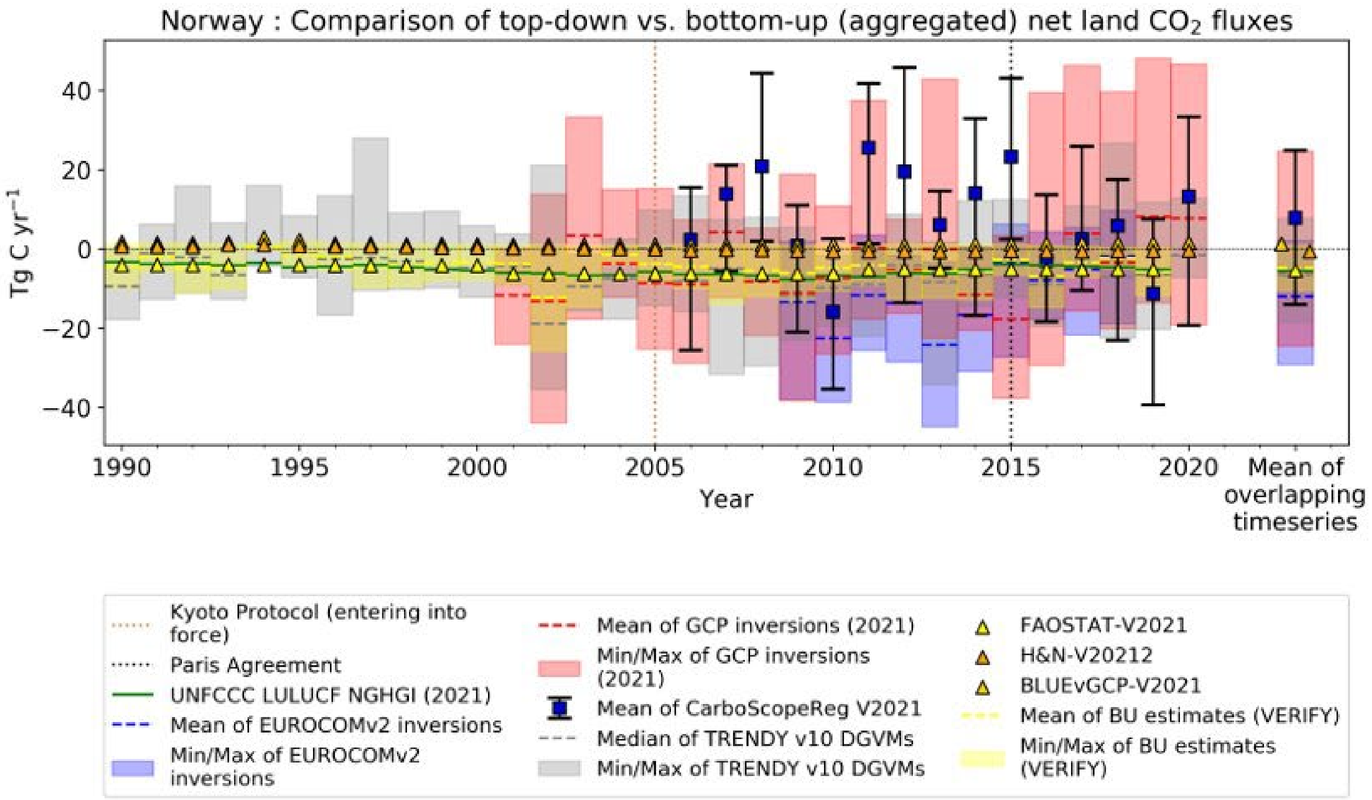
LULUCF using top-down inversions

There is a very large spread in inversions, though, the mean is quite similar to the UNFCCC inventories.
Inversions include much more process understanding and variability, making comparisons hard…



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Sub-national scale critical, but challenging in Norway

- Several challenges in estimating emissions at municipal level
  - Important stats in some sectors not available at municipal level
  - Privacy/confidentiality issues prevent SSB from releasing some data at local level
  - Can satellite data be used to verify emission totals? Large point sources?
- Some challenging sectors:
  - Navigation: Inconsistent with national inventory, and pushback from some municipalities on assumptions
  - Landfill emissions: Model-based, unclear how accurate
  - Agriculture: Based on activity (area, animal headcounts, …), many mitigation measures not captured
  - Industry: Only enterprises that report emissions to the agency or statsforvalteren – SSB data not disclosed due to confidentiality
- Can municipal emissions be improved using CO2MVS?

Will satellites help with landfill CH_4 in Norway? (not yet)

Most Norwegian landfills have emission rates of <0.1 tonnes per hours (t/h)

Municipal stats for 2020 (tCH4/h): Total 3.65, max 0.238 (Bergen), mean 0.011, median 0.001

This is mostly too diffuse for the current generation of satellites, need local measurements

Instrument	Availability	Target resolution	Species	Estimated CH_4 Point source Detection limit
TROPOMI	2017 - present	7×5.5 km^2	CH_4	~4 t/h (Jacob et al., 2016)
GOSAT/-2	2009- present	10 km diameter	CO_2, CH_4, N_2O	~7 t/h (Jacob et al., 2016)
OCO-2	2014 - present	3 km^2	CO_2	N/A
IASI	2006 - present	12 km diameter	N_2O	N/A
MicroCarb	Launch ~2023	4.5×9 km^2 (2×2 km^2 in zoom mode)	CO_2	N/A
PRISMA	2019 - present	30 m	CH_4	0.5 - 2 t/h (Guanter et al., 2021a)
Sentinel-2	2015 - present	20 m	CH_4	~3 t/h (Varon et al., 2021)
GHGSat	2016 - present	50 m (25 m)	CH_4	~1t/h (0.1 t/h) (Jervis et al., 2021)
Worldview-3	2014 - present	4 m	CH_4	~0.1 t/h (Sánchez-García et al., 2021)
MethaneSAT	Launch ~ 2022	130m × 400 m	CH_4	0.5 - 1 t/h (Elkind et al., 2020)
CarbonMapper	Launch ~ 2023	30-35 m	CO_2, CH_4	0.05 - 0.15 t/h (https://carbonmapper.org/)

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Source: EYE-CLIMA Proposal

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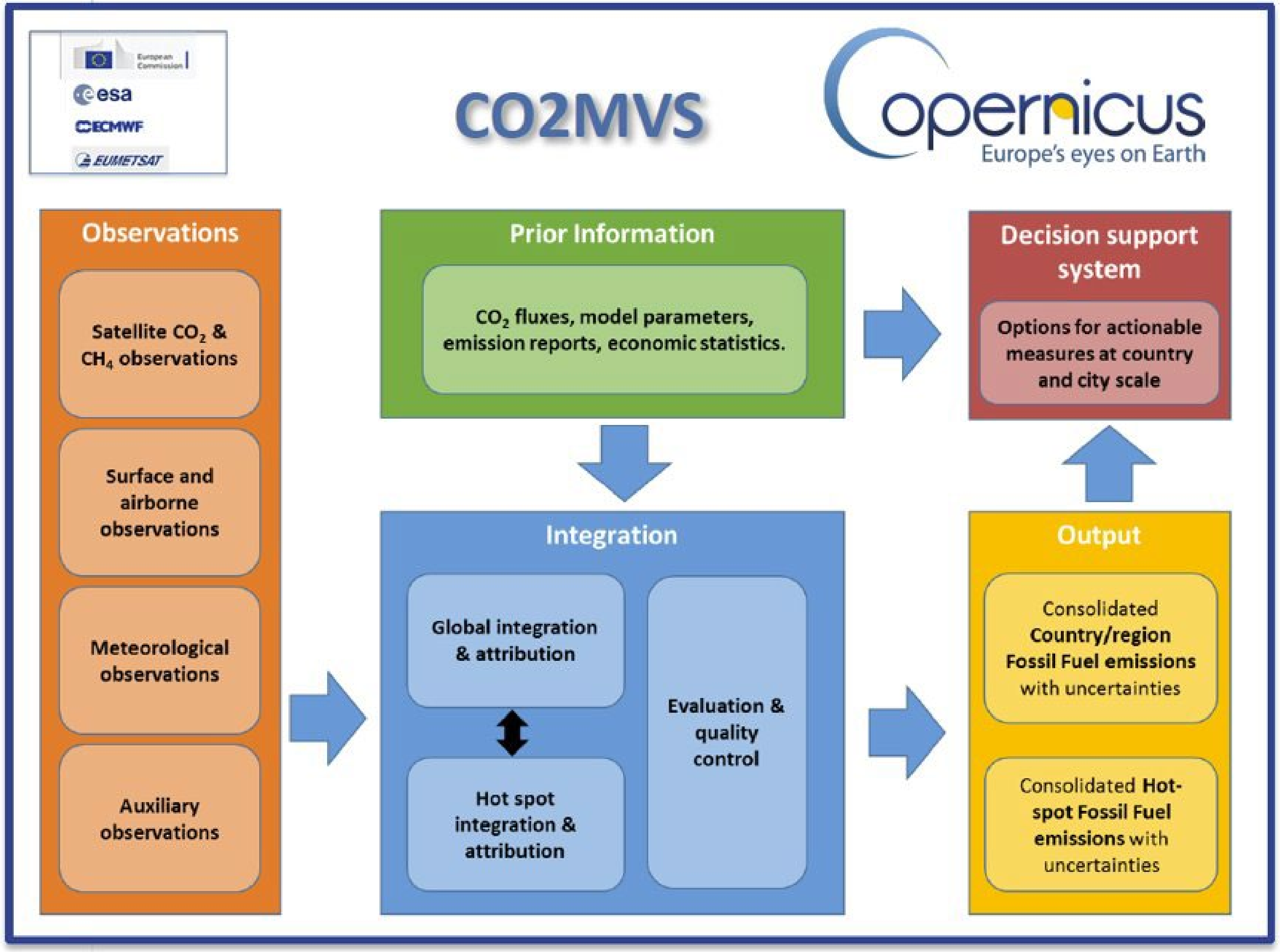

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Thank you

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