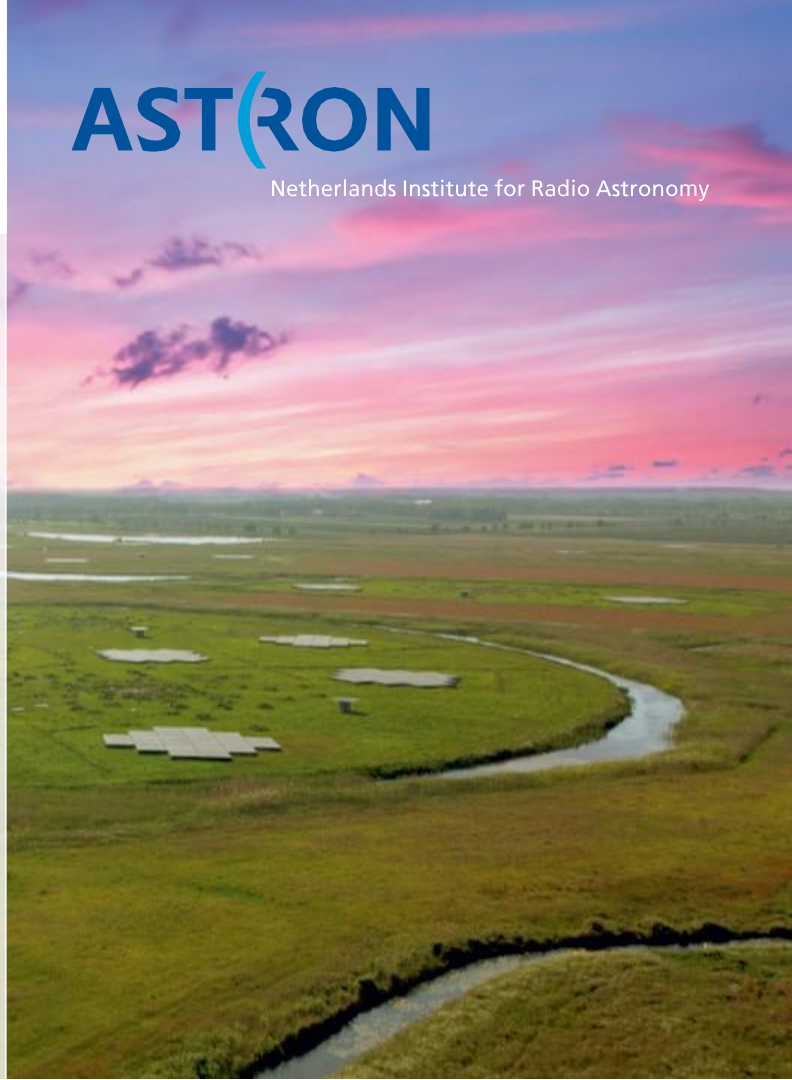


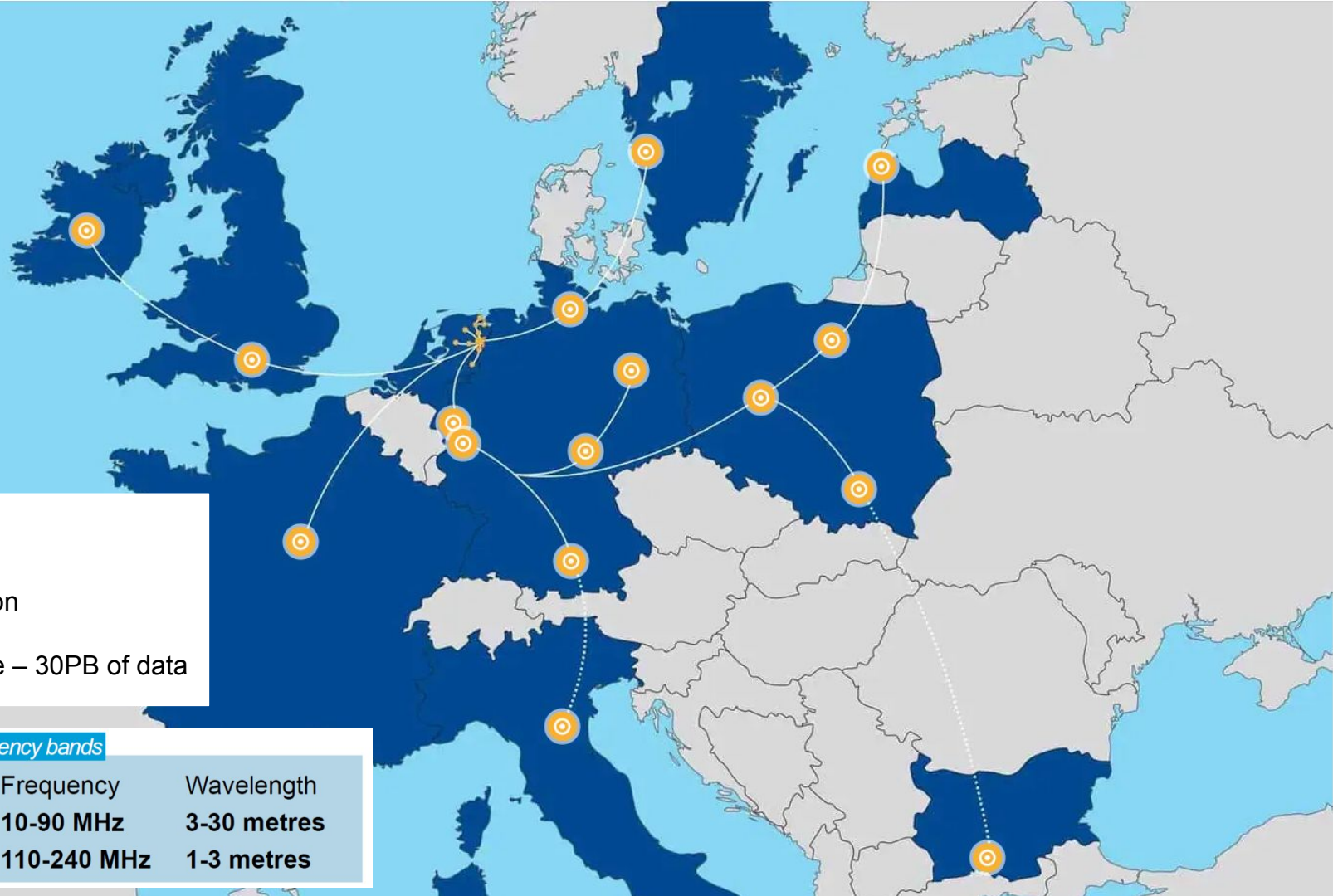
Affordable and sustainable large-scale distributed radio telescope processing

Presented by Morag Brown, on behalf of the LENSS team

Slides by Morag Brown, Ilse van Bemmelen and Chris Broekema







LOFAR2.0:

54 stations

6-9Gbps per station

394Gbps centrally

Long Term Archive – 30PB of data

LOFAR observing frequency bands

Band Name	Frequency	Wavelength
Low Band	10-90 MHz	3-30 metres
High Band	110-240 MHz	1-3 metres

Radio astronomy is intensive



A total of approximately 250 000 core hours were required for the data reduction process in order to arrive at the final image. This was split between calibration and imaging as 34% and 76%, respectively. The image covers a 7.4 deg^2 sky area at an angular resolution of $0.3'' \times 0.4''$ and a central rms noise level of $32 \mu\text{Jy beam}^{-1}$ is reached. This equates to a 1.4 GHz sensitivity of $7 \mu\text{Jy beam}^{-1}$, assuming a spectral index of $\alpha = -0.7$. This is comparable in depth to the deepest 1.4 GHz VLA image of the field [8].

7143 sources are detected at $6''$ in the covered area using a single 8 hour observation with an rms noise level of 70 uJy beam^{-1} . Of these 6397 (90%) are unresolved and 746 (10%) are resolved. Of those unresolved sources, 2568 (40%) had a high resolution counterpart detected at a $\text{SNR} > 5$. 293 of these sources are resolved (11%) and the other 2275 remain compact (89%).

TECHNIEK MAAKT JE WERELD

DE INGENIEUR

[Home](#) [Dossiers](#) [Tijdschrift](#) [Podcast](#) [KIVI Agenda](#) [Engineering Works](#) [Vacatures](#)

FOSSIELVRIJ
VLIEGEN



Zoeken



STROOM TE DUUR VOOR RADIOTELESCOOP LOFAR

15 SEPTEMBER 2022

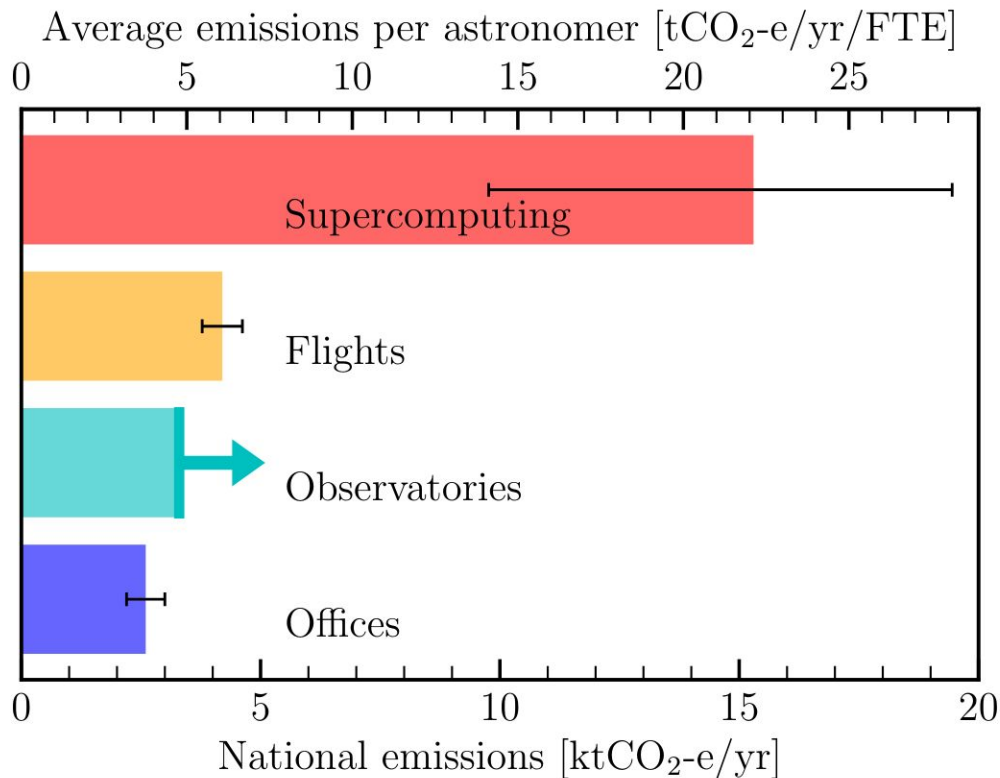


De energiecrisis maakt onverwachte slachtoffers. Zonder noodhulp kan de radiotelescoop LOFAR in Drenthe de stroomrekening niet meer betalen. De kosten zijn drie keer zo hoog sinds het energiecontract afgelopen zomer moest worden vernieuwd.

ARTIKELN

ASTRONOMEN HEBBEN LAST
VAN ELEKTROMAGNETISCHE
STRALING SATELIJETEN
SPACEX
5 JULI 2023

Significant part of our impact is computing



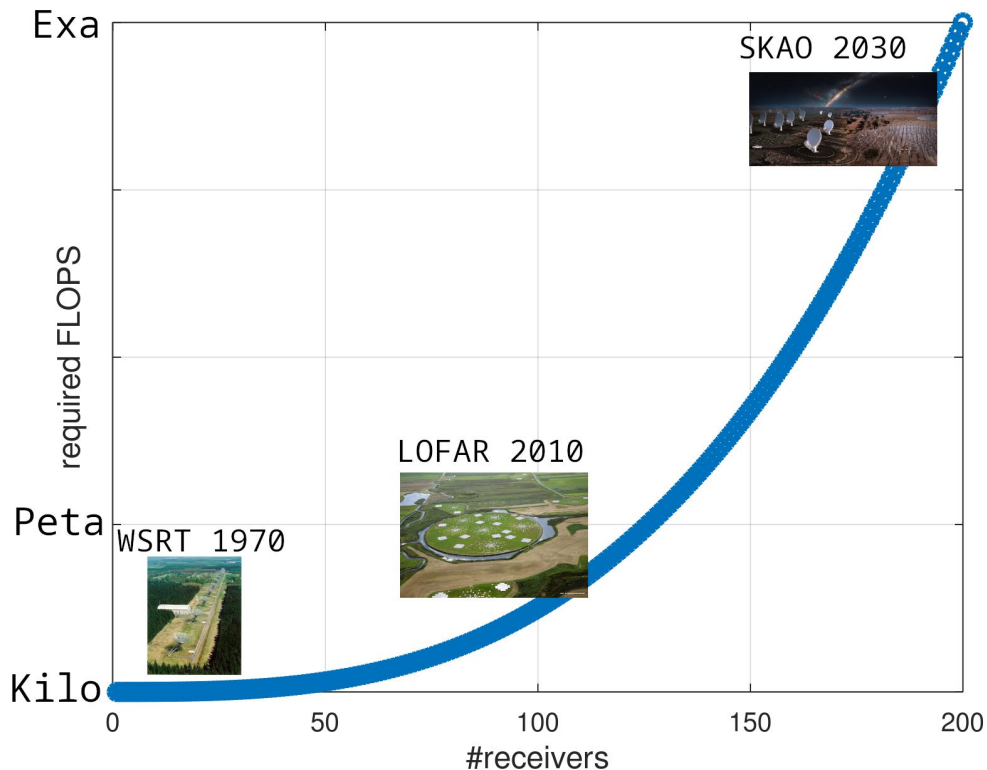
But our desire for knowledge demands...

- More resolution
- More sensitivity
- More data
- More high quality papers

Only going to get worse...

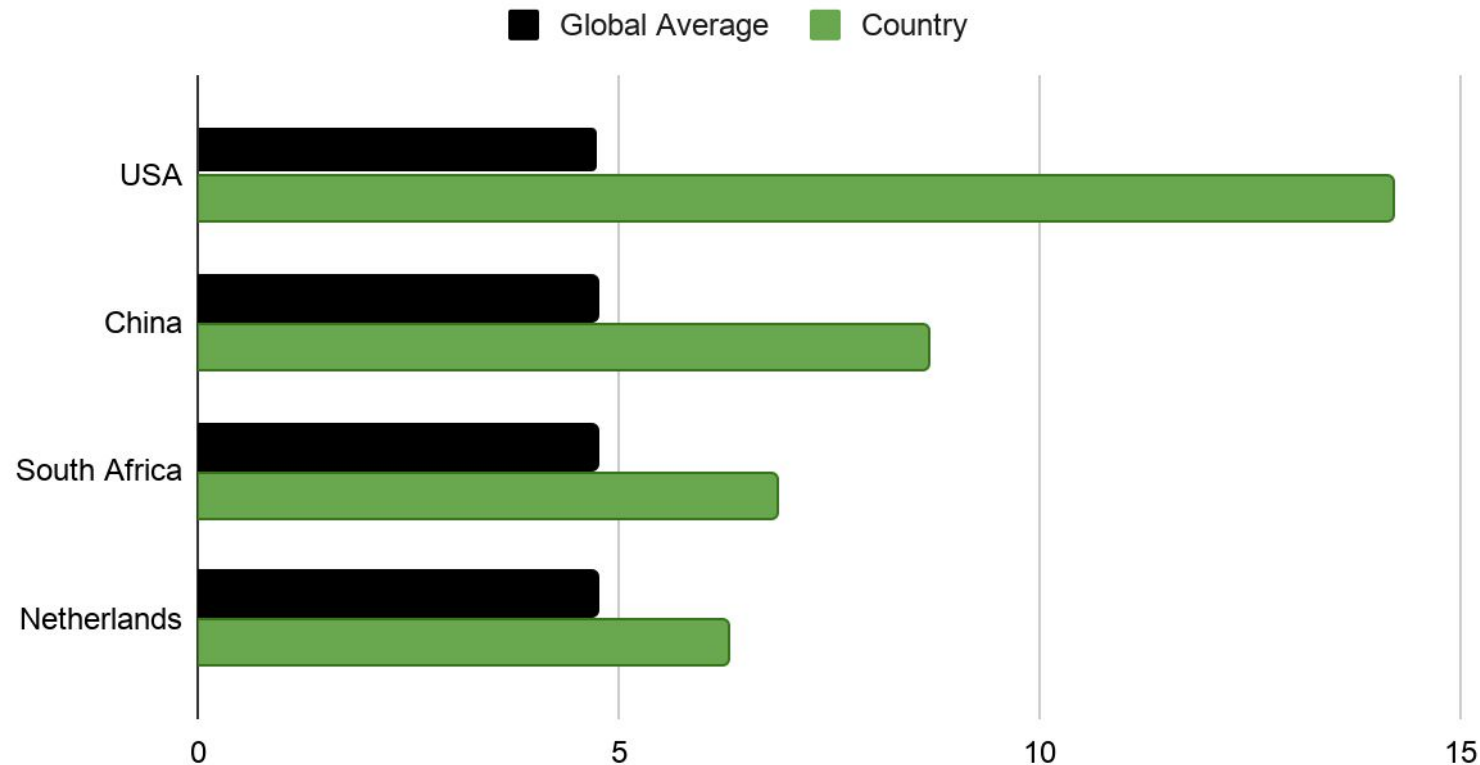


Compute power required for large scale telescopes



- Computational effort required **scales with $\sim O(n^3)$** of the number of receivers
- Size of the array adds an additional linear factor
- **Scientific output is already limited by limited computational resources rather than telescope time**
- Any telescope larger than the SKAO in terms of receivers/stations will very quickly become unaffordable to process
- This is unlikely to be solved by conventional technological developments (GPUs, Moore's law scaling, etc)
- **Data volume challenges not even taken into account here**

tCO₂ / person / year



How long until the impacts become so large that they fundamentally alter human society?

How long until the impacts become so large that they fundamentally alter human society?

1.5°C warming is likely to be reached or exceeded in the early 2030s.

How long until the impacts become so large that they fundamentally alter human society?

1.5°C warming is likely to be reached or exceeded in the early 2030s.

Even if all existing policies fully implemented as of now: **2.8°C warming by 2100.**

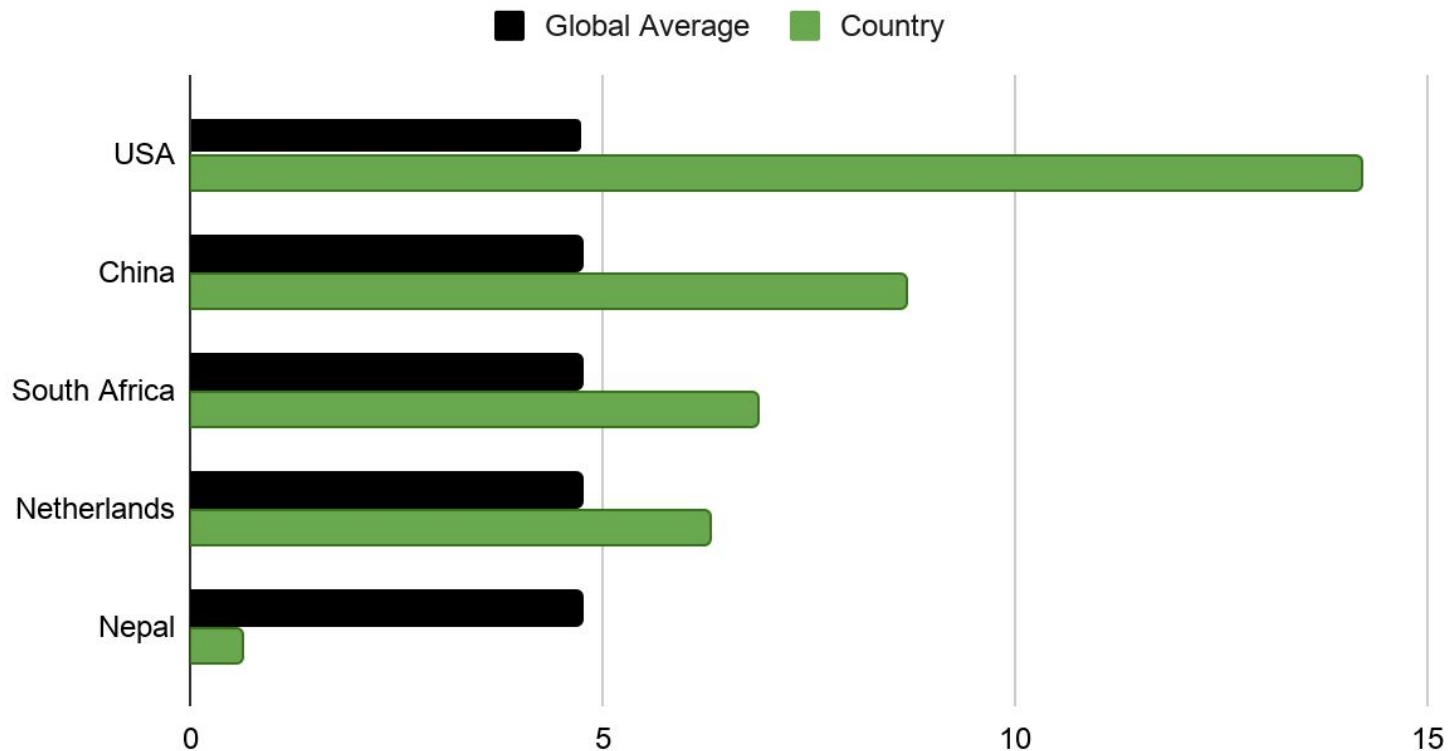
The New York Times · 2 days ago

Climate Change Raises Risk of Disasters Like Nepal Floods

Glaciers and permafrost in the Himalayas are melting faster as temperatures rise, though scientists are still studying the exact causes of this week's landslide.



tCO₂ / person / year



Introducing:



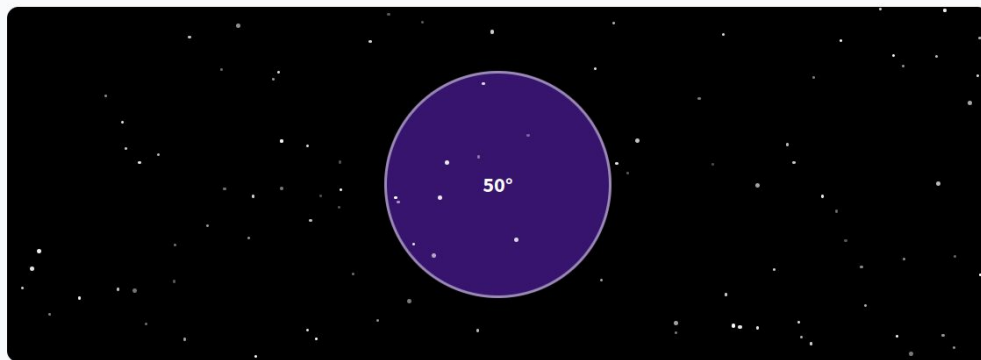
LENSS



LOFAR Enhanced Network for Sharp Surveys (LENSS)

Transforming radio astronomy with wider views and sharper details

LOFAR 2.0 ☒ LOFAR 2.0 + LENSS



Field of View

50° of sky observed at once

Resolution

0.3 arcseconds

Processing Time

12 hours per hour of observation

- Expanding LOFAR's field-of-view from 12 to 50 degrees of sky
- Achieving a resolution 20 times sharper using the full 2000 km baseline of antennas
- Processing observations **40 times faster**, turning weeks of computing into hour
- Maintaining its 2022 energy footprint despite these dramatic improvements

The LENSS commitment

Up to:

- 4x FoV
- 20x resolution
- 40x time to science

LENSS project **commits to not exceed 2022 energy budget**

(Some) risks and challenges

- How do we meaningfully **profile** the system so we know where to optimise?
 - Then ***what*** exactly do we optimise and ***how***?
 - How do we optimise **energy budget allocation**?
- What about the rising **cost of components** needed?
- How to **interface System's Engineering** and **Agile**?

(Some) risks and challenges

- How do we convince the scientific community **to care** about sustainable science?
 - Academia is competitive
 - No incentive to care about doing it sustainably
- And how do we guard against **Jevon's paradox**?

Plans and mitigations

- Project management
- Engineering
- Computer Science

Project management

- Key objective: **not exceeding environmental impact** of pre-existing instrument
 - First hard commitment to sustainability in large radio astronomy projects in the EU
- **Dedicated sustainability work package**
 - Define the scope
 - Ensure **uniform approach** within the project **with metrics**
 - Facilitate **verifiable sustainable development** with requirements

Project management

- Project Board
 - **Expert on green HPC** methods
- **Sustainability engineers**
 - Within the project as **WP leads**
 - **New hire** in the organization: **develop procedures** which enable us to embed project results in **long-term best practices** in whole ASTRON

Engineering

- **System's Engineering** based approach considering entire lifecycle
 - Including **components lifecycles + decommissioning**
 - **Sustainability Engineer** with a relevant technical background as **project engineer**
 - Identify **engineering hueristics** to assist Computer Science experts in system profiling and design
- Ensure proper **stakeholder buy-in and engagement**
- Investigate **incentives** for sustainable space science
 - And **social pressure** to adapt to sustainable practices

Computer Science

- Involved in **requirements analysis** from the start
- Identify and **mitigate bottlenecks**
 - e.g. minimise required read/writes and storage usage)
- Effective **use of VPUs** when better suited than FPUs
- Wide-spread introduction of **GPU^{*} accelerated code**
- **Algorithmic advances** implemented when possible
- Routine **monitoring** of performance and energy consumed
 - Monitoring **built in** from the start, **not afterthought**

My take



Sustainability is fundamentally a Systems Engineering problem

Project Engineer /Systems Engineer



- Provide a **systems engineering structure** within which Computer Scientists have **freedom to innovate**
- Provide interfaces/act as an **interface** between **various work packages/stakeholders**:
 - Relate Engineering and Computer Science concepts
 - Stakeholder engagement
 - **Does everyone have what they need to build their thing?**

Sustainability Engineer



- Focus on **Sustainable Development Goals**^{*}
 - Not just CO2 and energy consumption
- Raise **stakeholder awareness** about negative impact of scientific research
- **Begin questioning the bigger picture**

Number of Earths Needed for Human Use

Ecological Footprint



2022

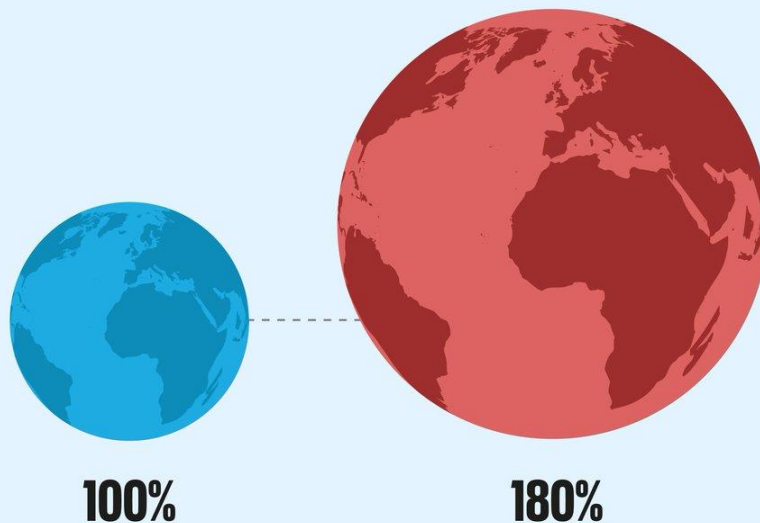


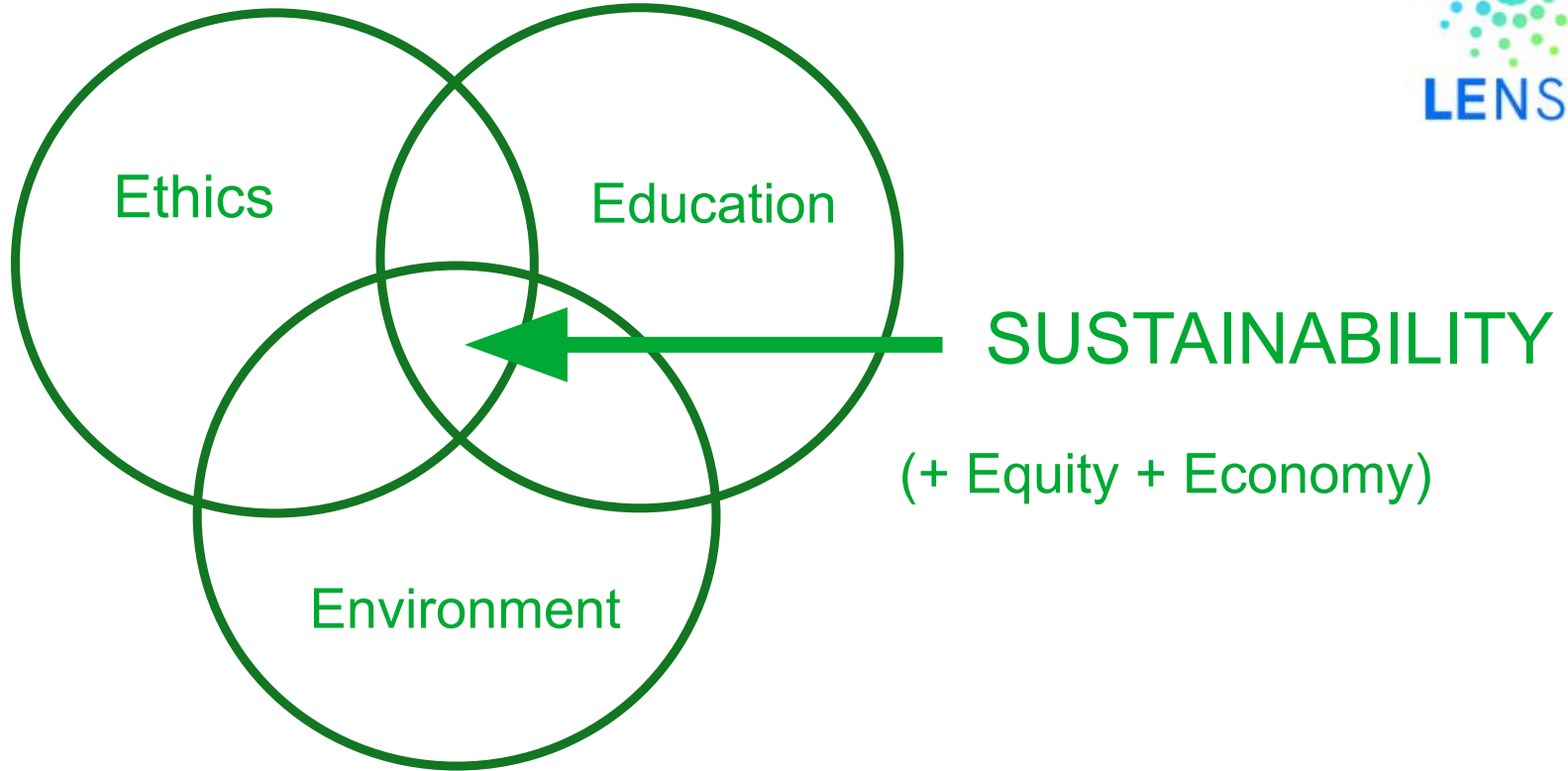
1995



1970

**HUMANKIND IS USING THE EARTH'S
NATURAL RESOURCES 1.8 TIMES FASTER
THAN THEY ARE ABLE TO REGENERATE**





All used in electronics/batteries etc

- Cobalt
- Coltan
- Gold
- Tantalum
- Tin
- Tungsten

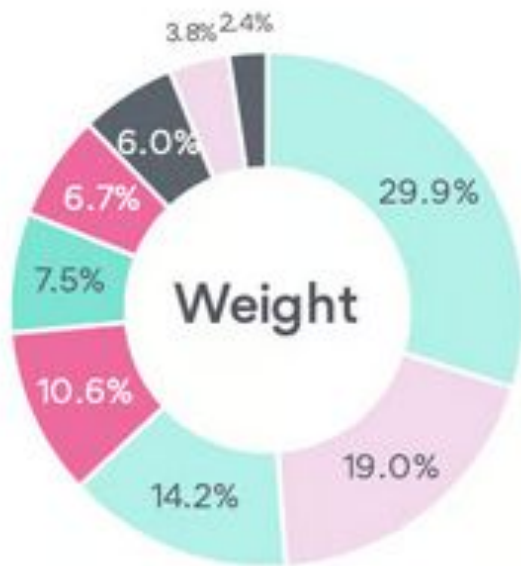
All used in electronics/batteries etc

- Cobalt
- Coltan
- Gold
- Tantalum
- Tin
- Tungsten

All **conflict minerals** linked to **slave/child labour** and exploitation

Nvidia's impact scores by SDG

+0.08 
Companies Global Impact



9 SDG covered (out of 17)		#Analyses	Weight	Impact Score	
	Industry, Innovation and Infrastructure	2	29.89%	+2.91	
	Climate Action	2	18.96%	+0.35	
	Peace, Justice and Strong Institutions	1	14.16%	-4.34	
	Responsible Consumption and Production	2	10.55%	-2.51	
	Decent work and Economic Growth	2	7.54%	-0.86	
	Gender Equality	1	6.68%	-3.03	
	Reduced Inequalities	1	6.03%	-0.39	
	Clean Water and Sanitation	1	3.77%	-2.57	
	Partnership for the Goals	1	2.42%	+2.50	

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for risks of and actions against forced labour in supply chains:

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for risks of and actions against forced labour in supply chains:
 - Average score:

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for risks of and actions against forced labour in supply chains:
 - Average score: 20/100

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for risks of and actions against forced labour in supply chains:
 - Average score: 20/100
 - NVIDIA (31st/45):

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for **risks of and actions against forced labour in supply chains**:
 - Average score: 20/100
 - **NVIDIA (31st/45): 11/100**

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for risks of and actions against forced labour in supply chains:
 - Average score: 20/100
 - NVIDIA (31st/45): 11/100
 - AMD (7th/45):

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for risks of and actions against forced labour in supply chains:
 - Average score: 20/100
 - NVIDIA (31st/45): 11/100
 - AMD (7th/45): 35/100

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for **risks of and actions against forced labour in supply chains**:
 - Average score: 20/100
 - NVIDIA (31st/45): 11/100
 - AMD (7th/45): 35/100
 - **3 passed**:
 - Samsung Electronics (61),
 - Hewlett Packard Enterprises (53)
 - Cisco Systems (51)

KnowTheChain 2025 Benchmark

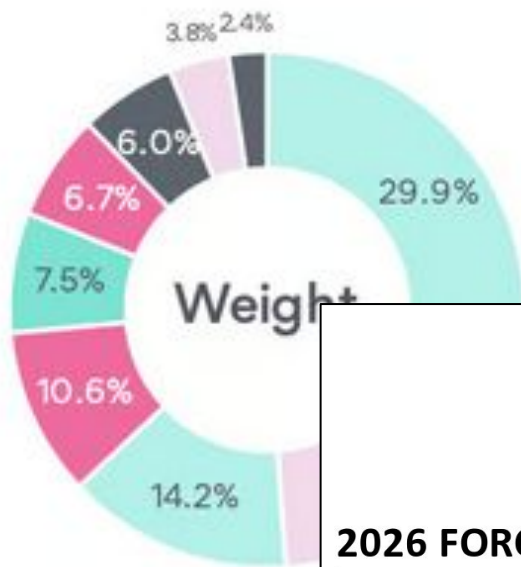
- 45 tech companies assessed for **risks of and actions against forced labour in supply chains**:
 - Average score: 20/100
 - NVIDIA (31st/45): 11/100
 - AMD (7th/45): 35/100
 - 3 passed:
 - Samsung Electronics (61),
 - Hewlett Packard Enterprises (53)
 - Cisco Systems (51)
 - **BOE Tech** (0th/45):

KnowTheChain 2025 Benchmark

- 45 tech companies assessed for **risks of and actions against forced labour in supply chains**:
 - Average score: 20/100
 - NVIDIA (31st/45): 11/100
 - AMD (7th/45): 35/100
 - 3 passed:
 - Samsung Electronics (61),
 - Hewlett Packard Enterprises (53)
 - Cisco Systems (51)
 - **BOE Tech** (0th/45): 0/100

Nvidia's impact scores by SDG

+0.08
Companies Global Impact



9 SDG covered (out of 17)	#Analyses	Weight	Impact Score	
Industry, Innovation and Infrastructure	2	29.89%	+2.91	
Climate Action	2	18.96%	+0.35	
Peace, Justice and Strong Institutions	1	14.16%	-4.34	
Responsible Consumption and Production	2	10.55%	-2.51	
Decent work and Economic Growth	2	7.54%	-0.86	



2026 FORCED LABOR, HUMAN TRAFFICKING, AND CHILD LABOR STATEMENT

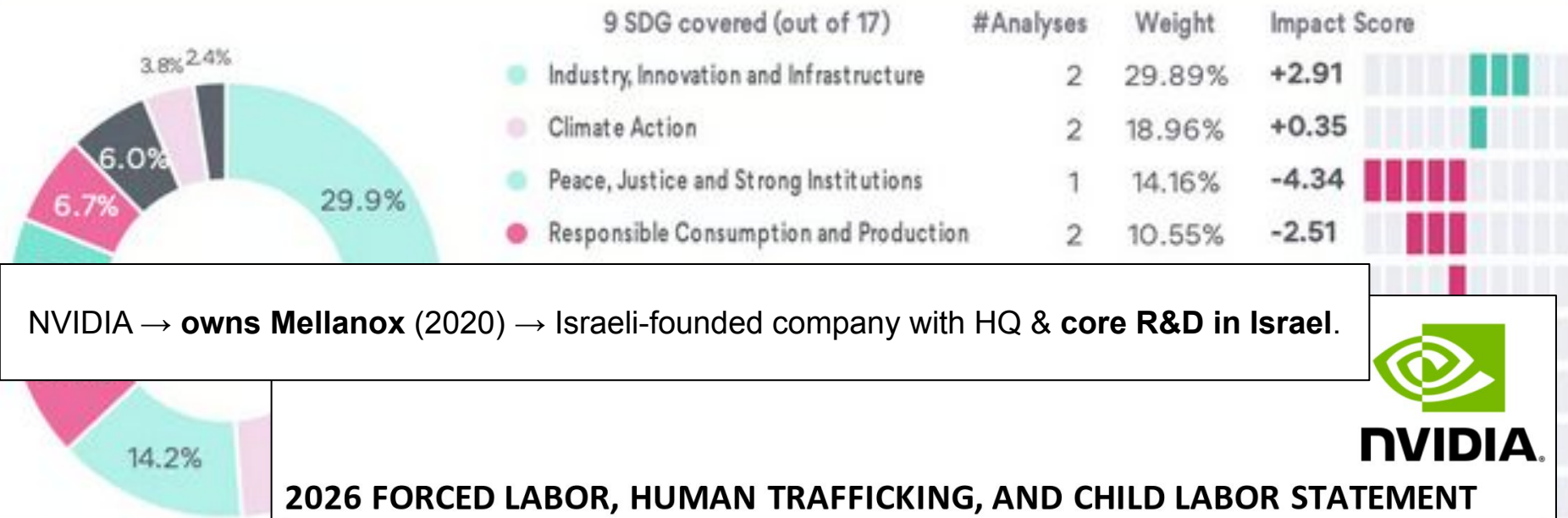
ASTRON

Netherlands Institute for Radio Astronomy

Source: <https://www.greendigest.co/p/nvidia-environmental-and-social-impact>
<https://www.nvidia.com/content/dam/en-zz/Solutions/about-us/documents/2025-Forced-Labor-Human-Trafficking-and-Child-Labor-Statement.pdf>
<https://www.sec.gov/Archives/edgar/data/1356104/000119312520119847/d921927d8k.htm>

Nvidia's impact scores by SDG

+0.08
Companies Global Impact



NVIDIA → **owns Mellanox** (2020) → Israeli-founded company with HQ & **core R&D** in Israel.



2026 FORCED LABOR, HUMAN TRAFFICKING, AND CHILD LABOR STATEMENT

What is actually needed?



Elon Musk  
@elonmusk

X.com

Extremely severe extinction events happen every 100M years or so and just switching to sustainable energy will not be enough to stop them.

What is actually needed?



Elon Musk  
@elonmusk

X.com

Extremely severe extinction events happen every 100M years or so and just switching to sustainable energy will not be enough to stop them.

Space satellites to control temperature and massive geo-engineering will be needed or it will be game over.

What is actually needed?



Elon Musk  
@elonmusk

X.com

Extremely severe extinction events happen every 100M years or so and just switching to sustainable energy will not be enough to stop them.

Space satellites to control temperature and massive geo-engineering will be needed or it will be game over

What is actually needed?

- **MUST** have rapid design and deployment of energy sustainable systems

What is actually needed?

- **MUST** have rapid design and deployment of energy sustainable systems

AND

- Large scale awareness campaigns
- Mass social, ethical and regulatory reform
- Boycott of competitive, capitalist culture

Hold people like Musk and companies like NVIDIA accountable

What is actually needed?

- **MUST** have rapid design and deployment of energy sustainable systems

AND

- Large scale awareness campaigns
- Mass social, ethical and regulatory reform
- Boycott of competitive, capitalist culture

How do we incentivize ethics?



ASTRON

Netherlands Institute for Radio Astronomy

Thank you!
brown@astron.nl