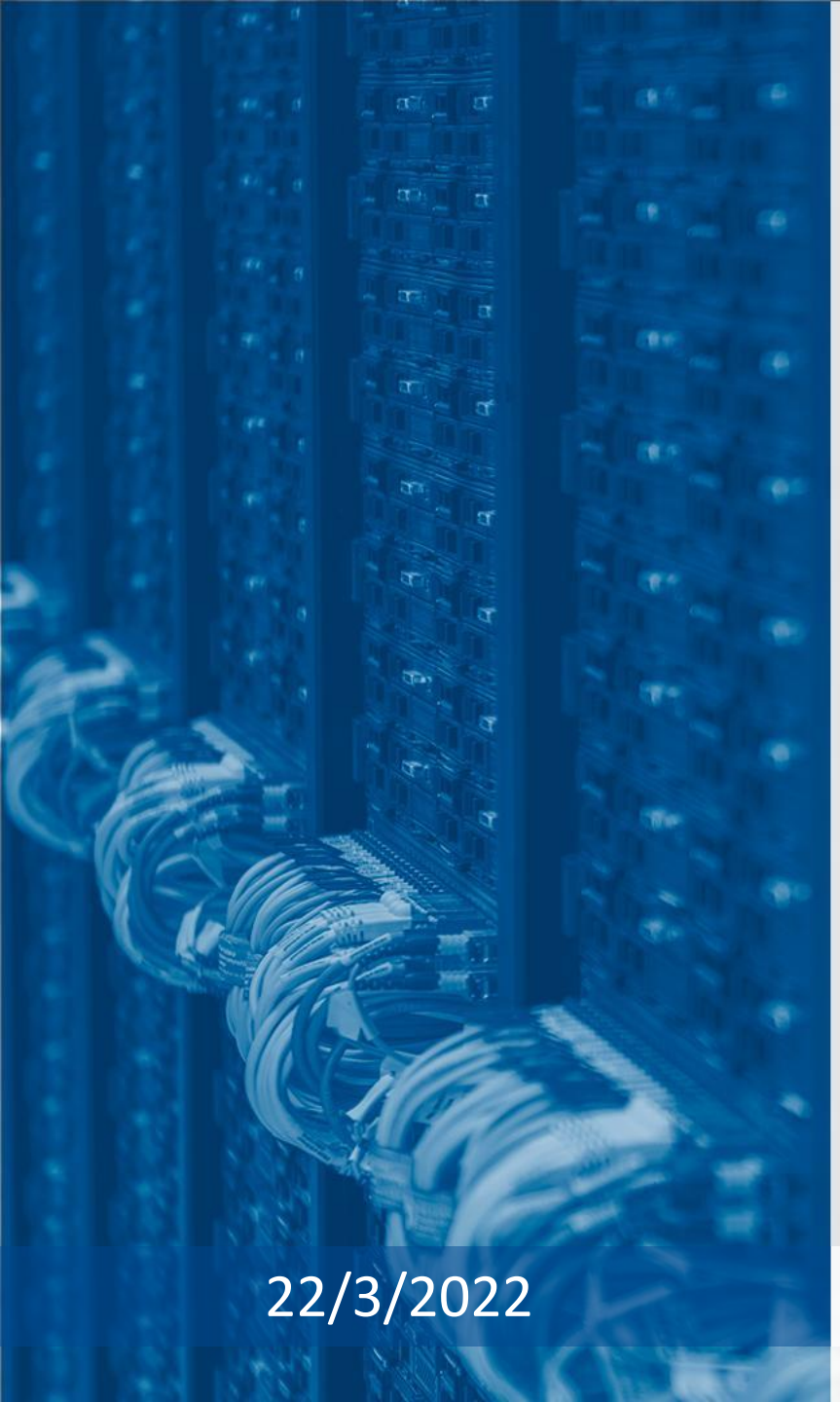

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Towards minimising carbon footprint of climate modelling: Modelling centre perspective

Mario Acosta, Pierre-Antoine Bretonnière and Carbon footprint group at BSC

22/3/2022

WCRP Workshop on Future of Climate Modelling

Why?

- IPCC 1.5°C report (2018): reduce CO_2 emissions by 7% every year to meet 0 emissions objective by 2050
- Increasing expectations from the society to meet these goals
- Growing initiatives within the scientific community
- First step: carbon footprint

Measure greenhouse gases emitted by activities at BSC-Earth in CO_2 equivalents (CO_2e)

Measure energy cost by activities such as coordinated experiments as CMIP6 using a common set of metrics (CPMIP)

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Carbon footprint of BSC-Earth 2018

Taken into account:

- Commuting
- Computing infrastructure
- Building & Infrastructures
- Travels

Total budget of BSC-Earth: **?**

Equivalent per person: **?**

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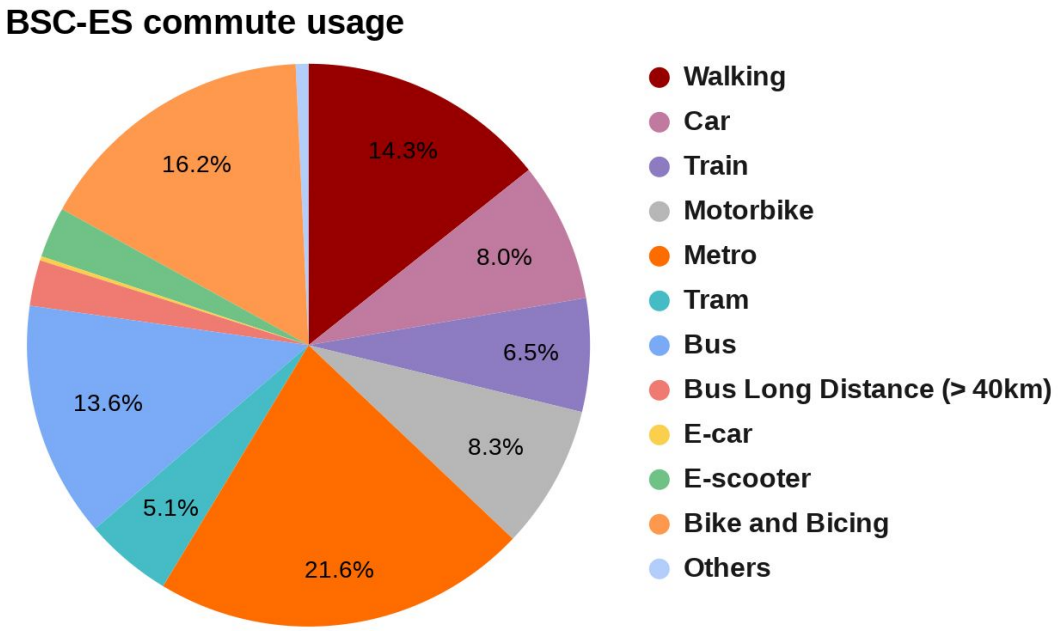
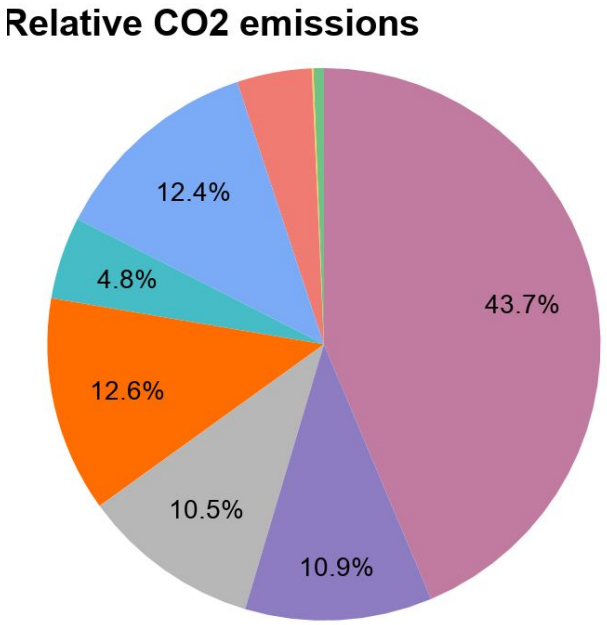
Commuting





Total budget of BSC-ES :

29 tCO_2e / yr

Equivalent per person:

0.4 tCO_2e / person / yr

- **Walking and biking** produce **0** emissions (31% of BSC-ES people).
- **44%** of commuting emissions due to **cars** (8% of BSC-ES people).

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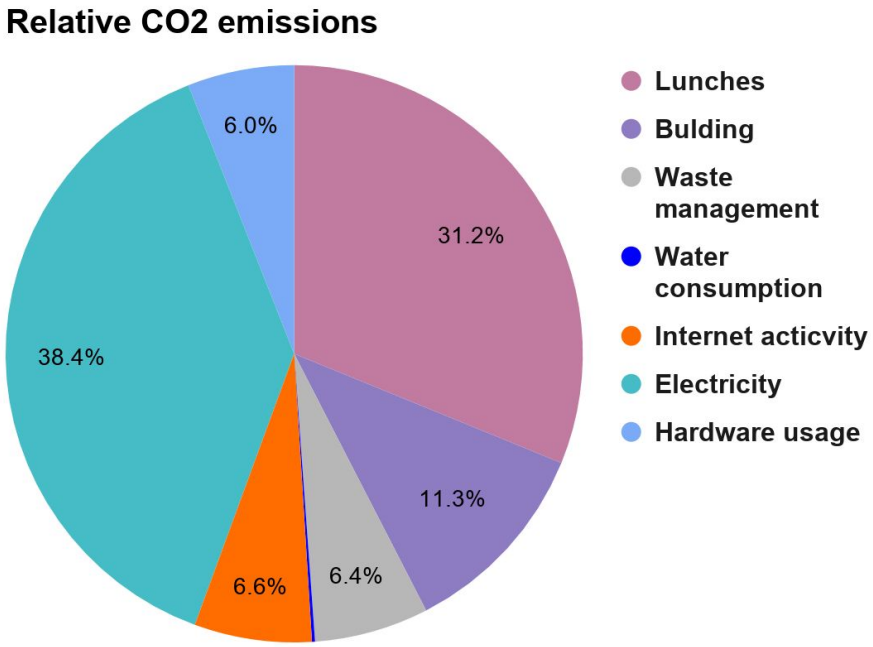
Building & Infrastructures



Total budget of BSC-ES :

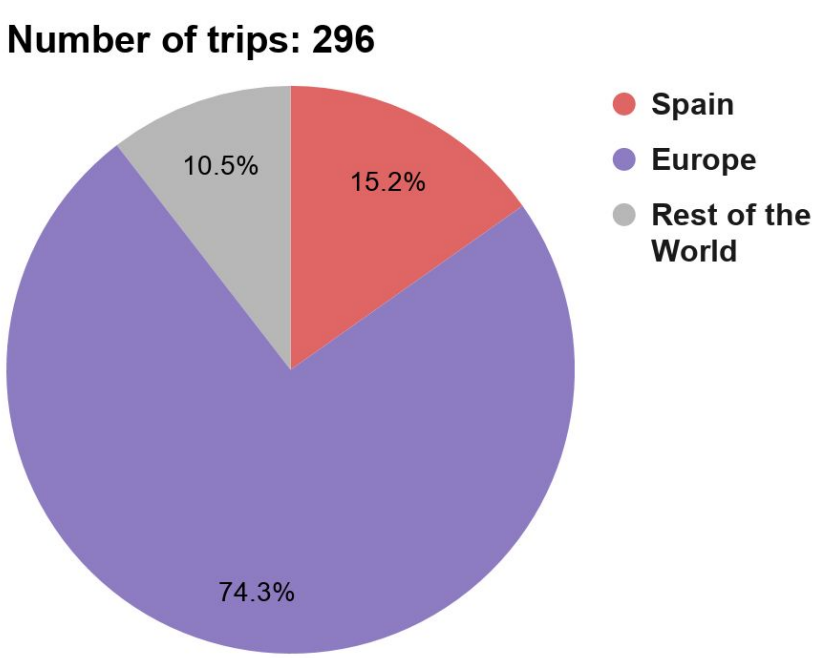
117 tCO_2e / yr

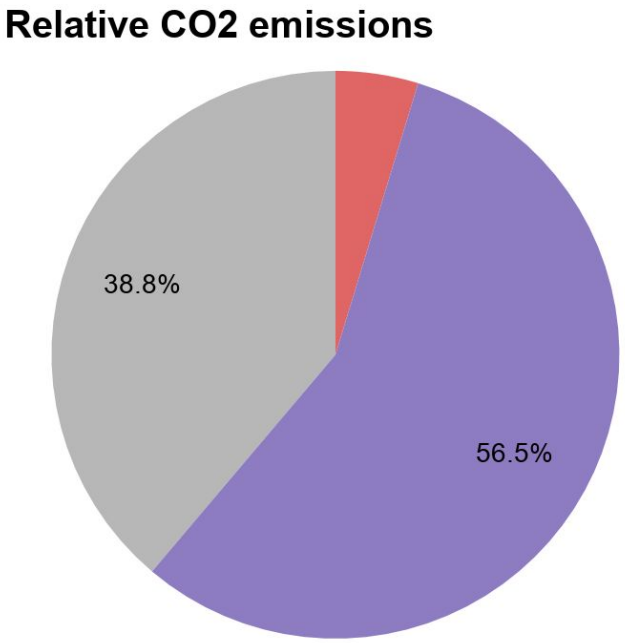
Equivalent per person:

1.5 tCO_2e / person / yr

- **Electricity and meals** account for 2/3 of emissions.
- High uncertainty!

Travels





Total budget of BSC-ES :

255 tCO_2e / yr

Equivalent per person:

3.2 tCO_2e / person / yr

- **Plane >> train**: e.g. Bcn-Madrid, 300 >> 40 kg CO_2e / trip
- **Overseas trips** are high contributors

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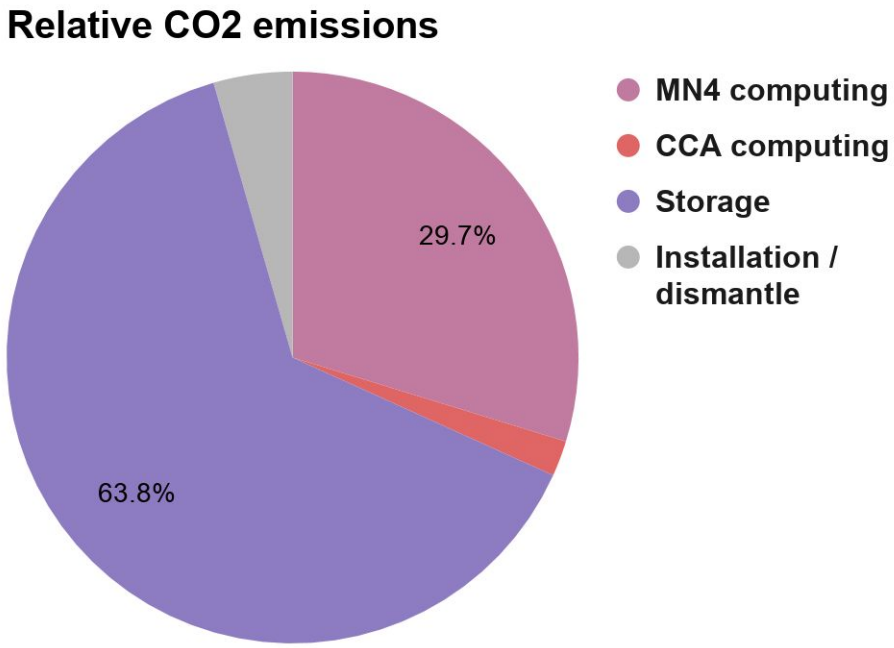
Computing infrastructure



Total budget of BSC-ES :

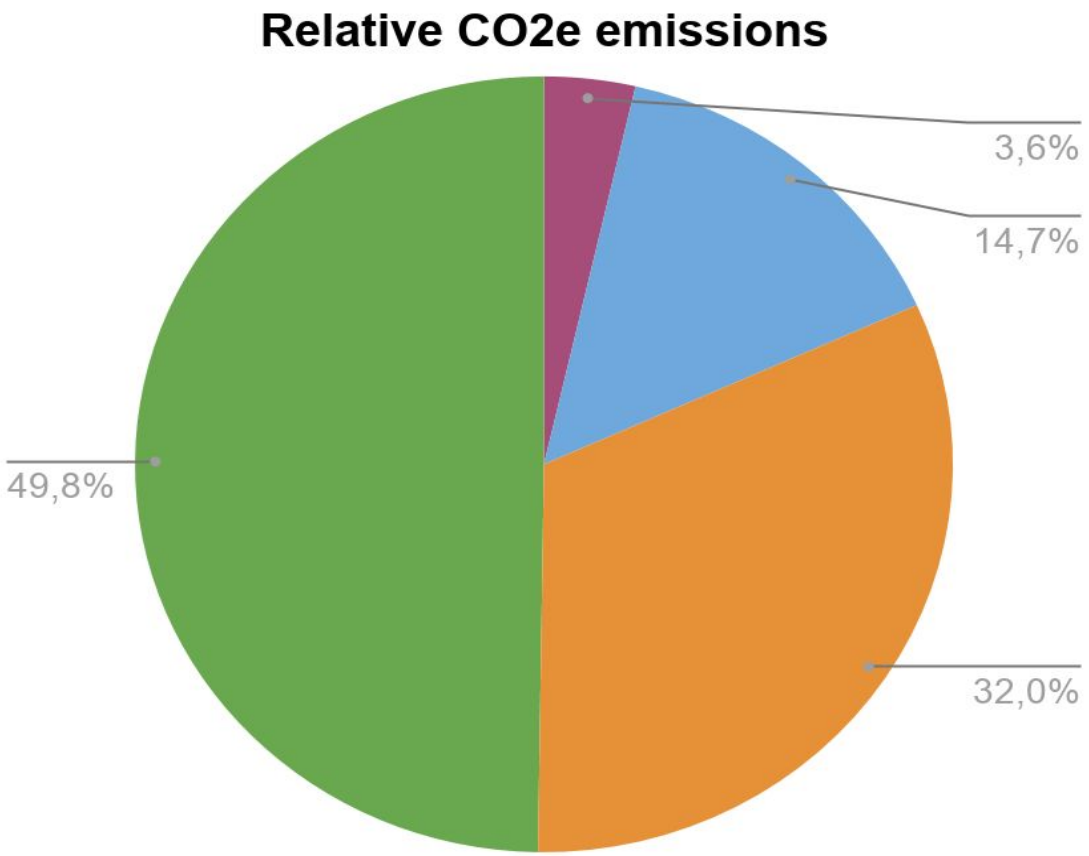
397 tCO_2e / yr

Equivalent per person:

5 tCO_2e / person / yr

- Storage main contributor (tape system will ↓ emissions)
- Highly dependent on electricity sources

Carbon footprint of BSC-Earth 2018



Taken into account:

- **Commuting** **29** tCO_2e / yr
- **Computing infrastructure** **397** tCO_2e / yr
- **Building & Infrastructures** **117** tCO_2e / yr
- **Travels** **255** tCO_2e / yr

Total budget of BSC-Earth **798** tCO_2e / yr

Equivalent per person **10** tCO_2e / yr

Bcn: 2; Spain: 5; World: 5 (tCO_2e / yr)

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From awareness to action?

- Carbon footprint: what's next?
  - Updating annually, compare pandemic and non-pandemic years
  - Incorporating CO_2 accounting to management tools, ↓ uncertainty
- Taking action, individual and collective. What if we…
  - Use 100% renewable energy: ↓60% CO_2e
  - Fly less:
    - ➢ Use video conference: cost-effective (win-win)
    - ➢ Take the train
  - Use the analysis to introduce optimizations in the computing part

Why?

- IPCC 1.5°C report (2018): reduce CO_2 emissions by 7% every year to meet 0 emissions objective by 2050
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Measure greenhouse gases emitted by activities at BSC-Earth in CO_2 equivalents (CO_2e)

Measure energy cost by activities such as coordinated experiments as CMIP6 using a common set of metrics (CPMIP)

CPMIP metrics (1, 2)

Metric	used to evaluate ...
Simulation Year Per Day (SYPD)	how efficient is your sim job per each year of the simulation
Core-hours Per Year (CHPY)	how efficient is your sim job with respect to the number of parallel resources used
Complexity	the number of prognostic variables per component
Actual SYPD	how affect queue time and interruptions to the complete experiment
Parallelization	total number of cores allocated for the run
Energy Cost Per Year (JCPY)	how much energy is needed per each year of simulation
Memory Bloat	the ratio between actual and ideal memory size
Data Output Cost	how much time and resources are used performing I/O
Data Intensity	the amount of data produced per compute-hour
Coupling Cost	how much time and resources are used in the cost of the coupling algorithm as well as load imbalance

(1) Balaji et al. 2017, CPMIP: measurements of real computational performance of Earth system models in CMIP6
(2) Mario Acosta et al. 2021, CPMIP performance metrics evaluation for CMIP6 and community advice

We collect the metrics for 11 models/institutions, 32 CMIP6 configurations

Carbon footprint CMIP6 analysis

CMIP6 Experiments: Institutions/Models	Useful Simulated Years	Useful Core-Hour (Mh)	Total Energy Cost (Joules)	PUE	CF (g CO2/kWh)	Total Carbon Footprint (CO2)
EC-Earth (BSC)	28,105	31.3	1.24E+12	1.35	357	165t
CNRM-CERFACS	47,000	160	6.18E+12	1.43	40	97t
IPSL	75,000	150	8.72E+12	1.43	50	172t
CMCC	965	1.99	1.61E+12	1.84	408	329t
UKMO	37.237	683	2.67E+13	1.35	87	868t
DKRZ	1,276	5.52	4.09E+11	1.19	184	24t
NCC-NORESM2	23,096	27.23	1.69E+12			
NERC	640	55.497	2.17E+12	1.10	0*	
MPI	24,175	968.116	6.20E+11	1.19	184	37t

*Green tariff according to NERC

Carbon Footprint = Total Energy Cost (MWh) * Conversion Factor (CF) * Power Usage Effectiveness (PUE)

The IS-ENES3 project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824084

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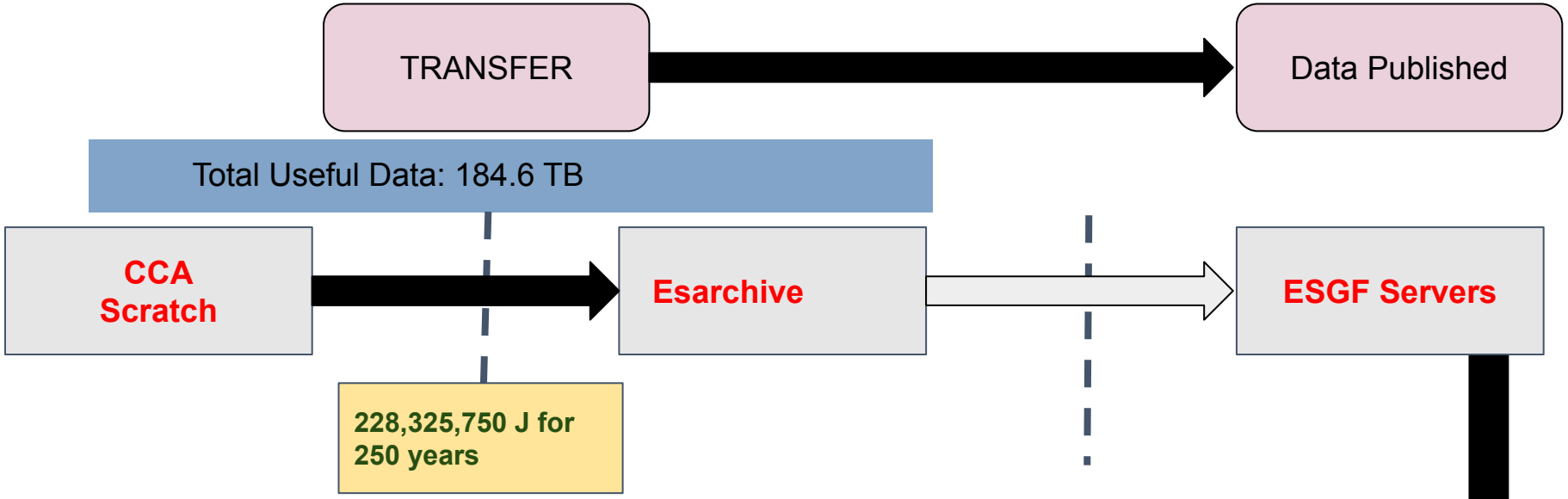
CMIP6 analysis: Data Transfer



Transfer process and data availability (10 years) represent a **5.13%** of additional consumption compared to the production of the data.

Storage consumption : 75 KW/PB
Per year for the data reported (J): **33,689,500**
Total Energy for 10 years: 336,895,000

Real copy

No real transfer, only quality checks

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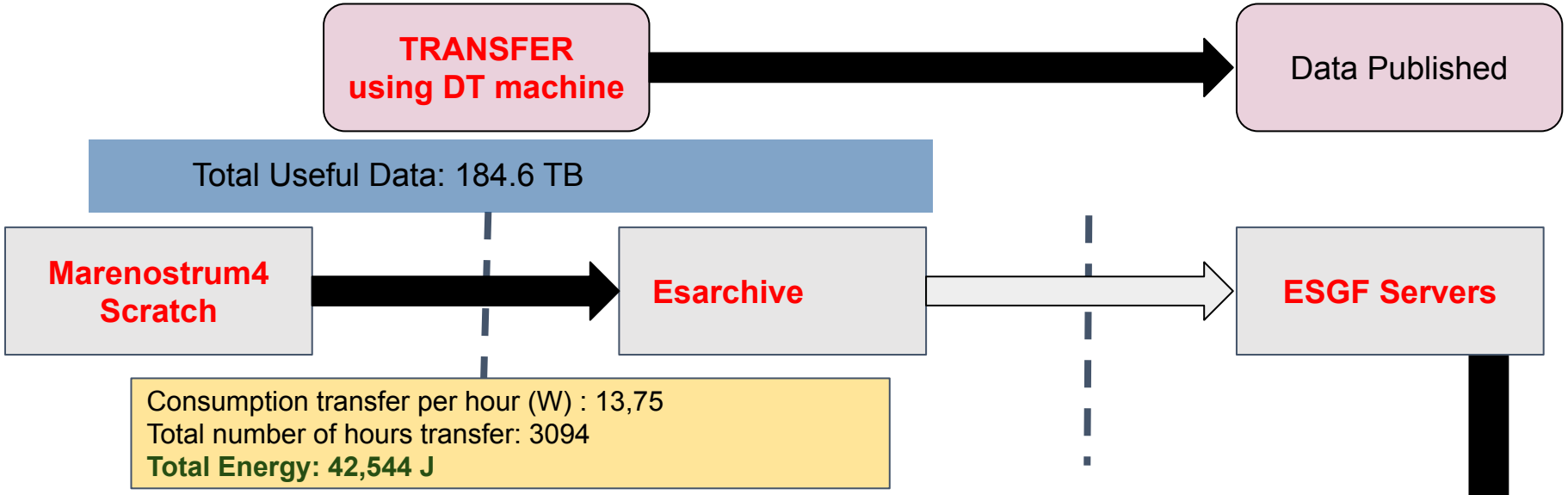
CMIP6 analysis: Data Transfer



Transfer process and data availability (10 years) represent a **3.05%** of additional consumption compared to production on the data. **Transfer process is reduced a 99%.**

From awareness to action?

- Carbon footprint: what's next?
  - Updating annually, compare pandemic and non-pandemic years
  - Incorporating CO_2 accounting to management tools, ↓ uncertainty
- Taking action, individual and collective. What if we…
  - Use the analysis to introduce optimizations in the computing part
    - ➢ A standard as CPMIP metrics and a coordinated collection as ISENES3 work done allow us to work in the reduction of the most expensive parts of the workflow.

Thank you

mario.acosta@bsc.es