The fast and the Sustainable:

Unleash the Power of Sustainable IT & High-Performance Green Code

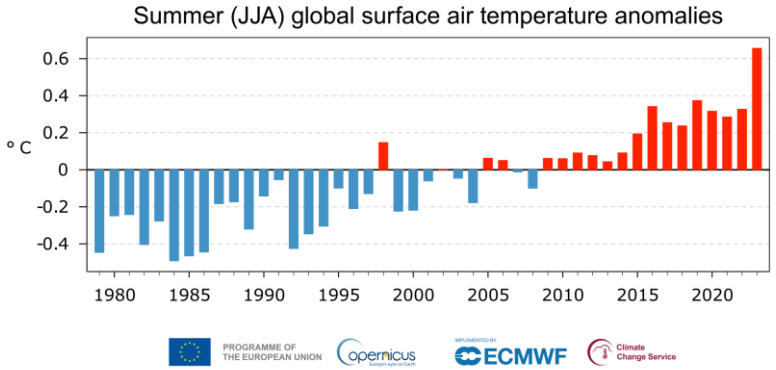
Alexandru – Madalin Ghenea & Marc Cortada Bertomeu

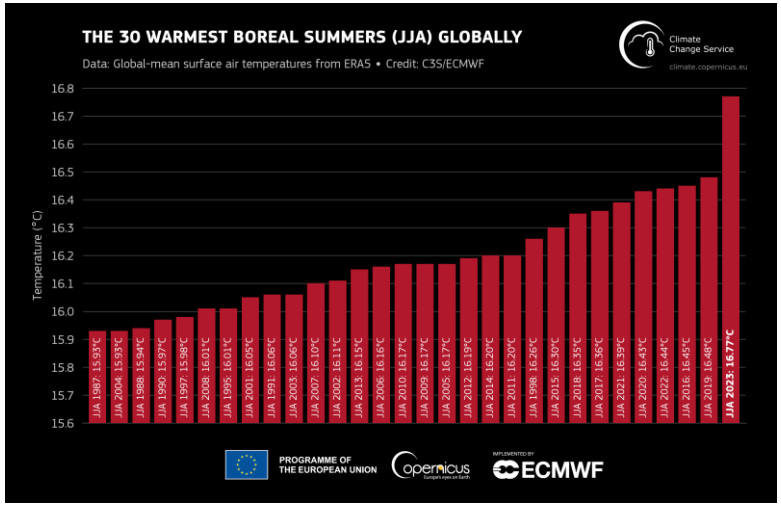
October 2023

do your thing

Climate change is accelerating

June - August 2023 - hottest three-month period on record*

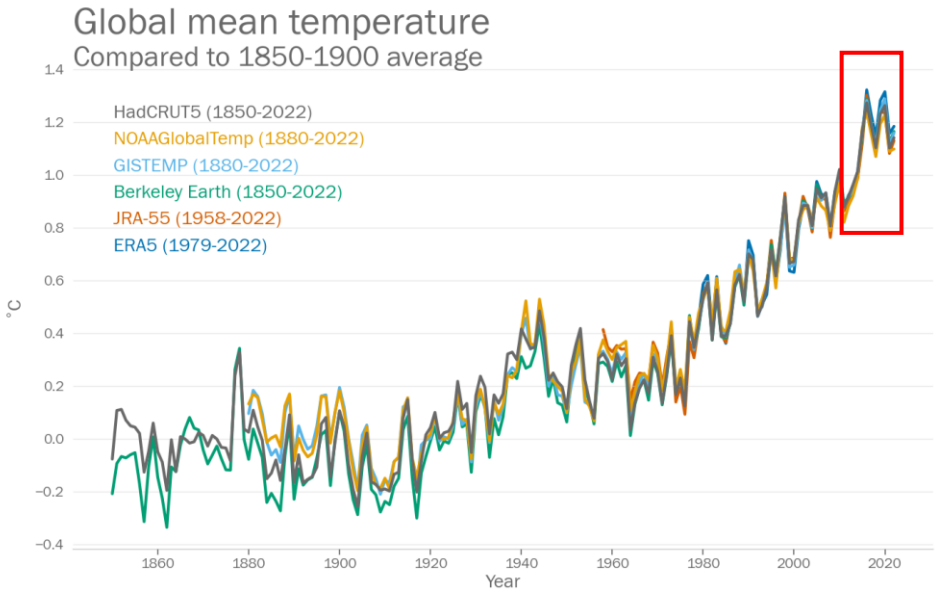




* According to World Meteorological Organization

Climate change is accelerating

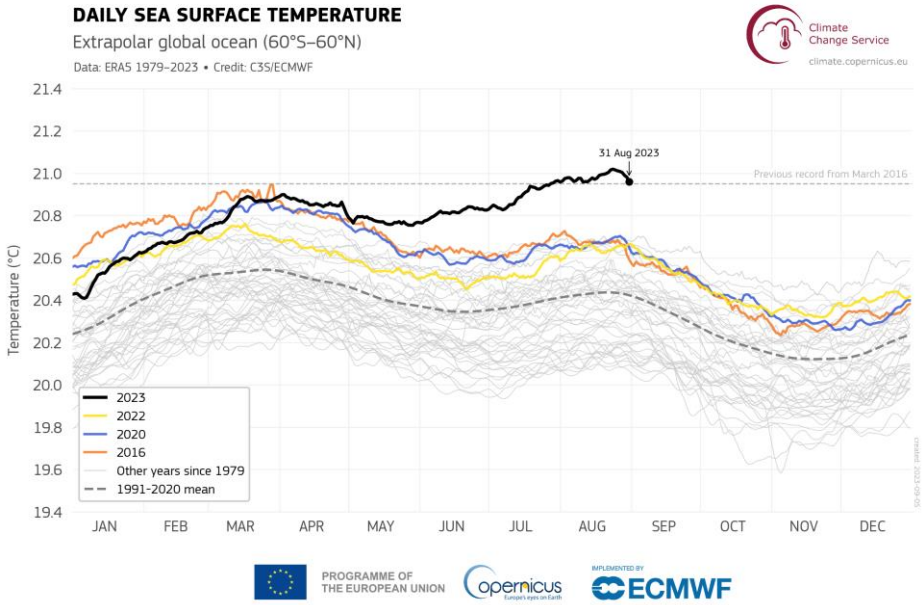
8 out last 10 years were the warmest years on record*



* According to World Meteorological Organization

Climate change is accelerating

Record breaking sea temperature this year*



* According to World Meteorological Organization

Carbon emissions in ICT*

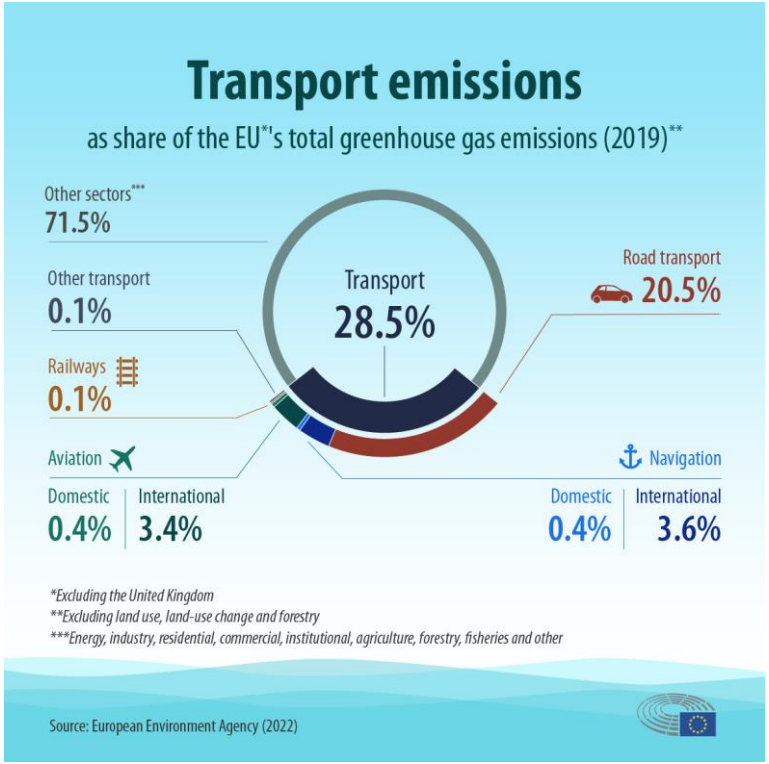
ICT represents 3-5% of global carbon emissions

* According to European Commission

Carbon emissions in ICT

Aviation represents
3.8% in EU*

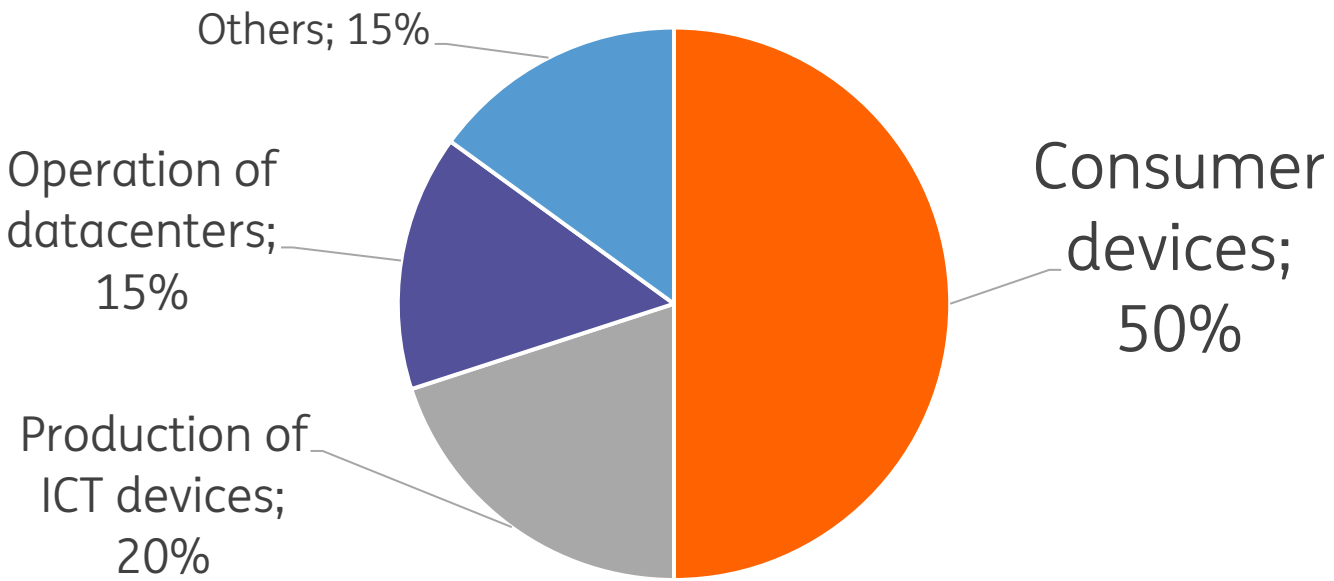
~3% worldwide**



* According to European Parliament
** Multiple sources

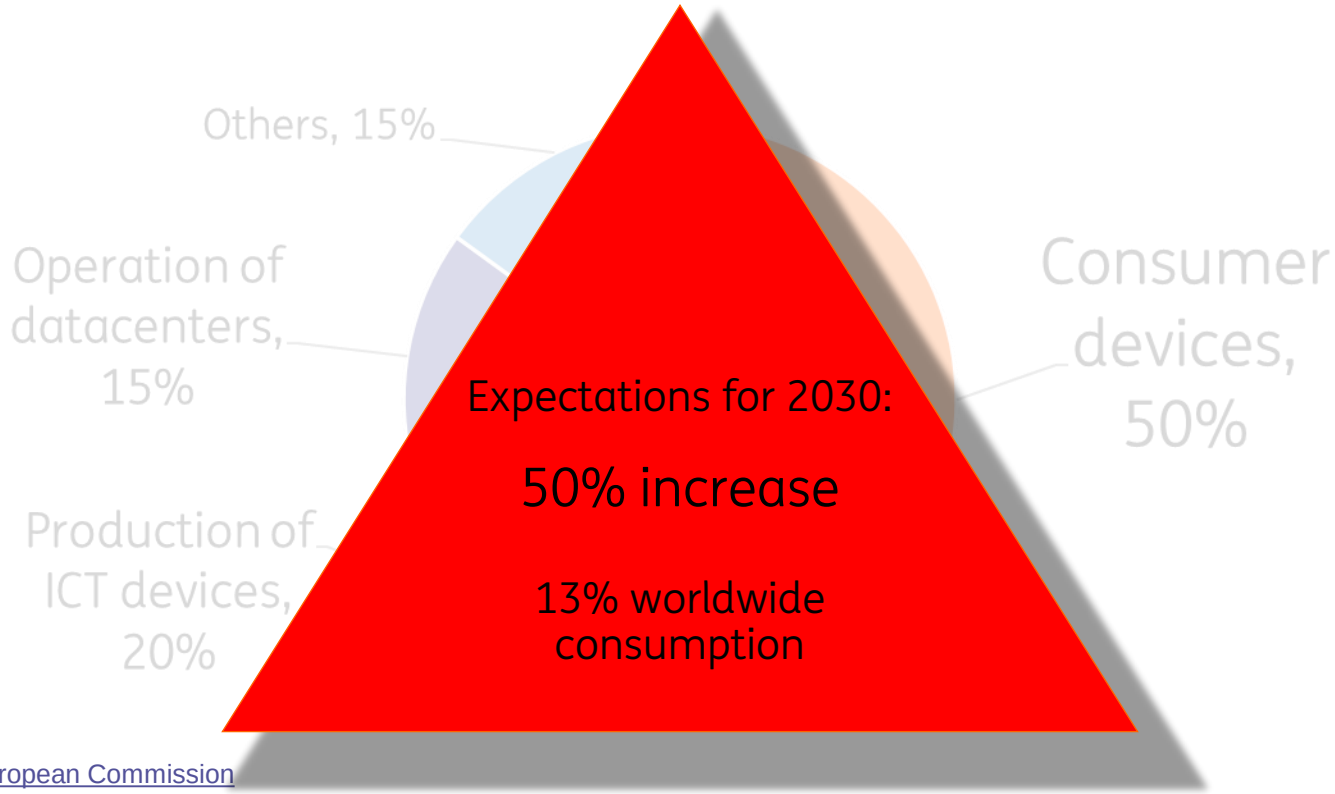
Energy consumption of ICT technologies 2020*

ICT represents 7% out of the worldwide energy consumption



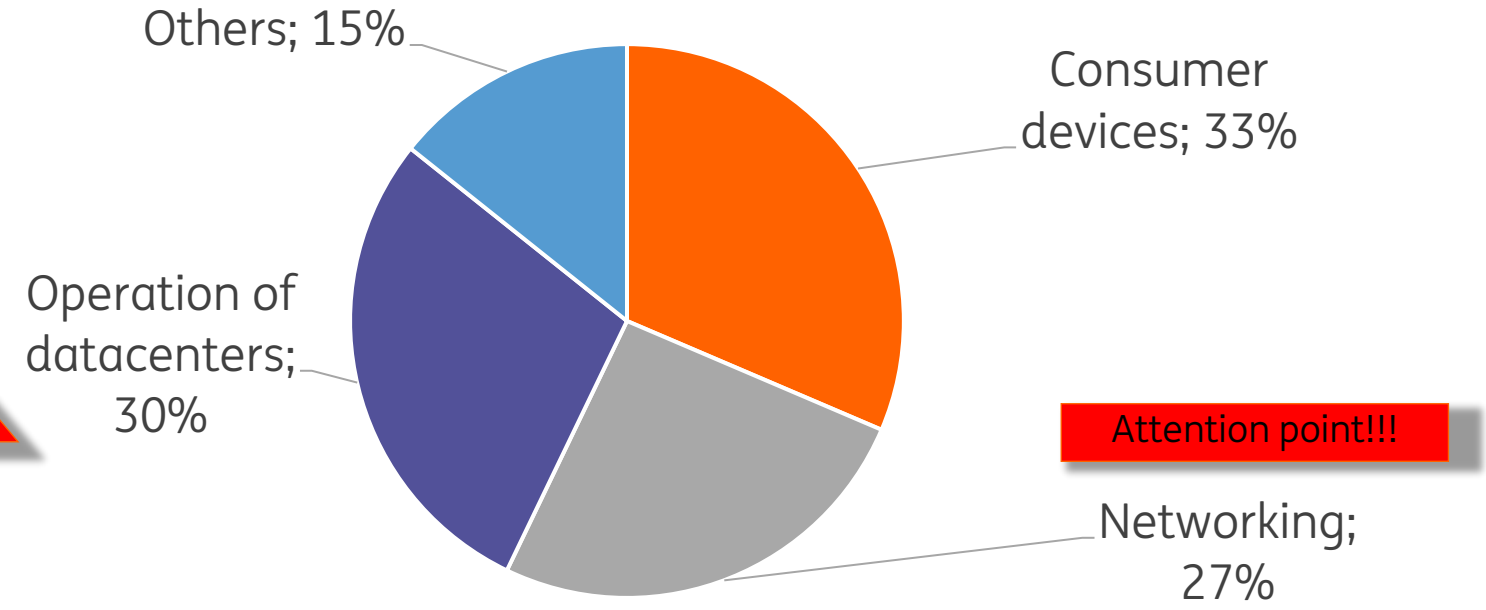
* According to European Commission

Energy consumption of ICT technologies 2020*



* According to European Commission

Energy consumption of ICT technologies expectations for 2030*



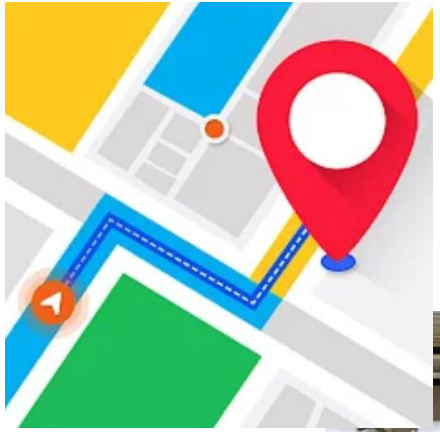
Doubled

Attention point!!!

* According to European Commission

It’s fair to mention

ICT contributes to reduce the CO2 emissions

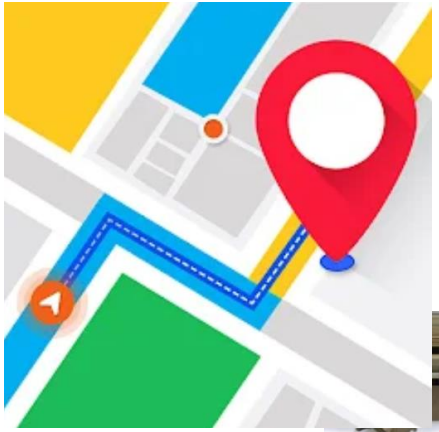


It’s fair to mention

ICT contributes to reduce the CO2 emissions

But,

CO2 emissions in ICT are significant and growing



Agenda

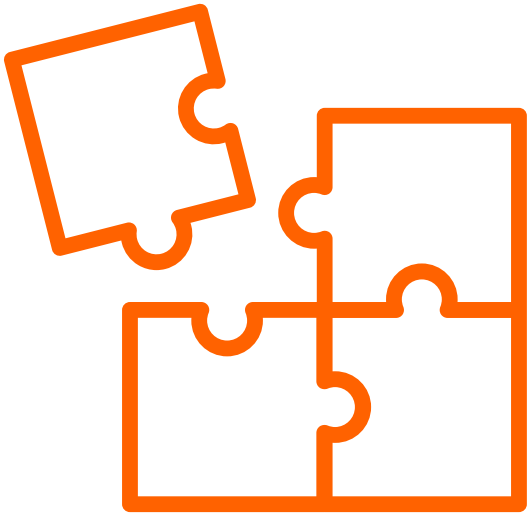
- Key concepts
- Software carbon intensity
- Green patterns & good practices
  - Demand shifting
  - Storage
  - Performance improvements in code
- Conclusions

Agenda

- Key concepts
- Software carbon intensity
- Green patterns & good practices
  - Demand shifting
  - Storage
  - Performance improvements in code
- Conclusions

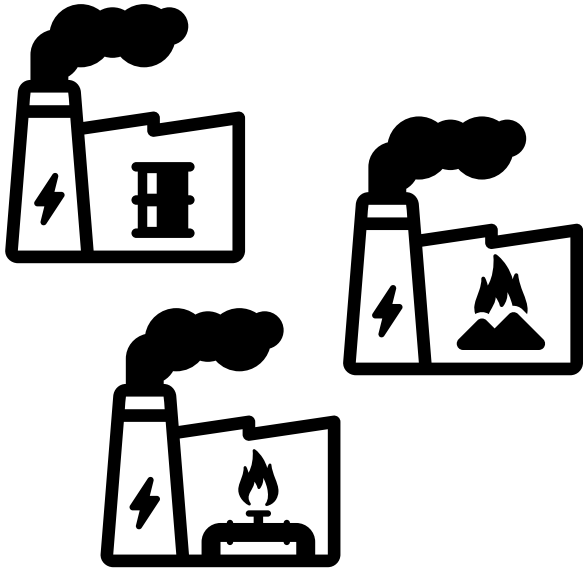
Key concepts

- Carbon awareness
- Carbon intensity
- Software Carbon Intensity



Energy sources

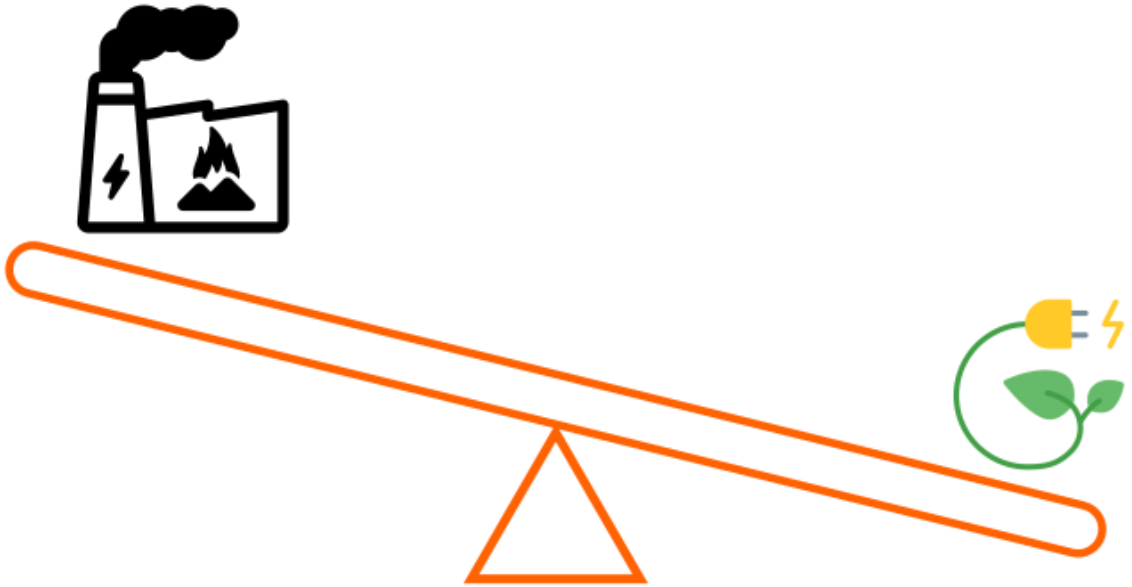
High carbon sources



Low carbon sources

Carbon awareness

- Do more when energy comes from low carbon sources
- Do less when energy comes from high carbon sources

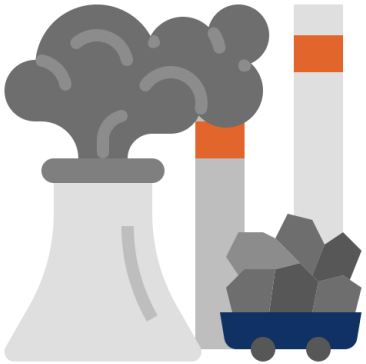


Carbon intensity

How much CO2 is emitted per kilowatt-hour

Carbon intensity

How much CO2 is emitted per kilowatt-hour



High carbon intensity

Low carbon intensity

Agenda

- Key concepts
- Software carbon intensity
- Green patterns & good practices
  - Demand shifting
  - Storage
  - Performance improvements in code
- Conclusions

Measuring carbon emission for software

If you can't measure it, you can't improve it

Peter Ferdinand Drucker

- Management consultant, educator and author

Measuring carbon emission for software

Let’s introduce a formula to measure Software Carbon Intensity:

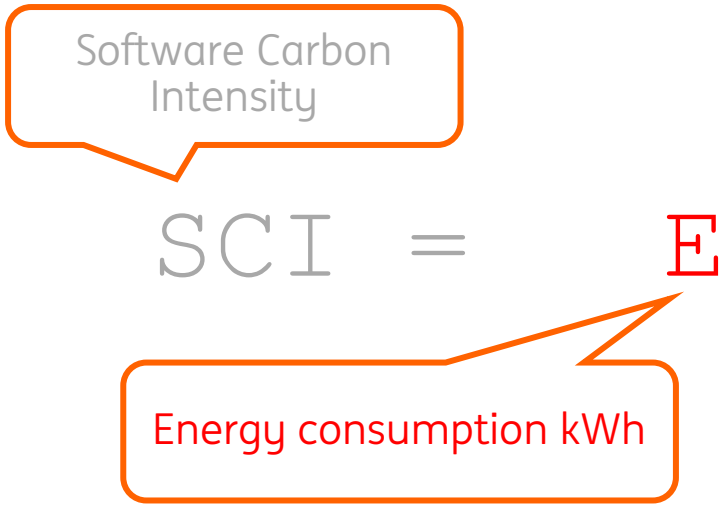
Software Carbon Intensity

$$SCI =$$

Measuring carbon emission for software

Green Software Foundation

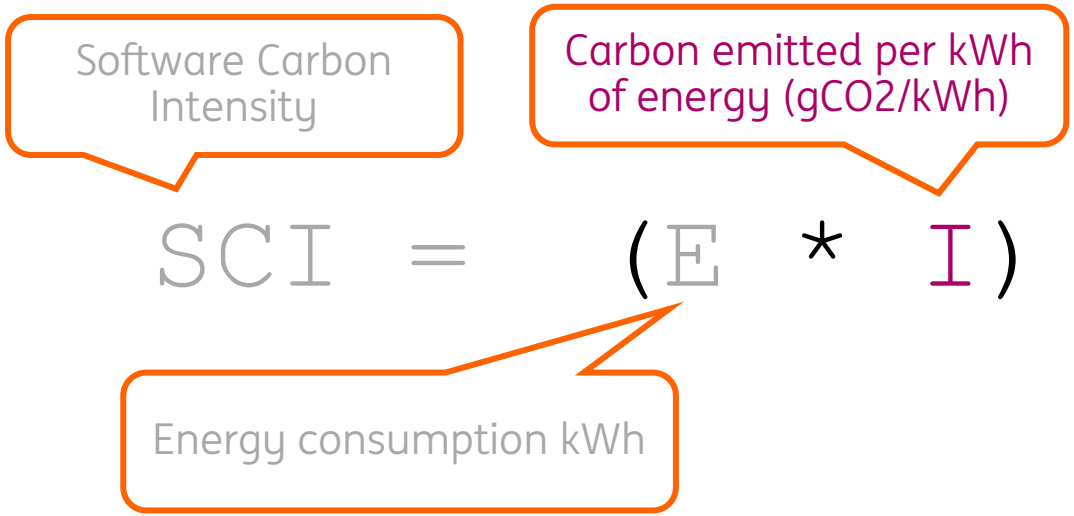
Let’s introduce a formula to measure Software Carbon Intensity:



Measuring carbon emission for software

Green Software Foundation

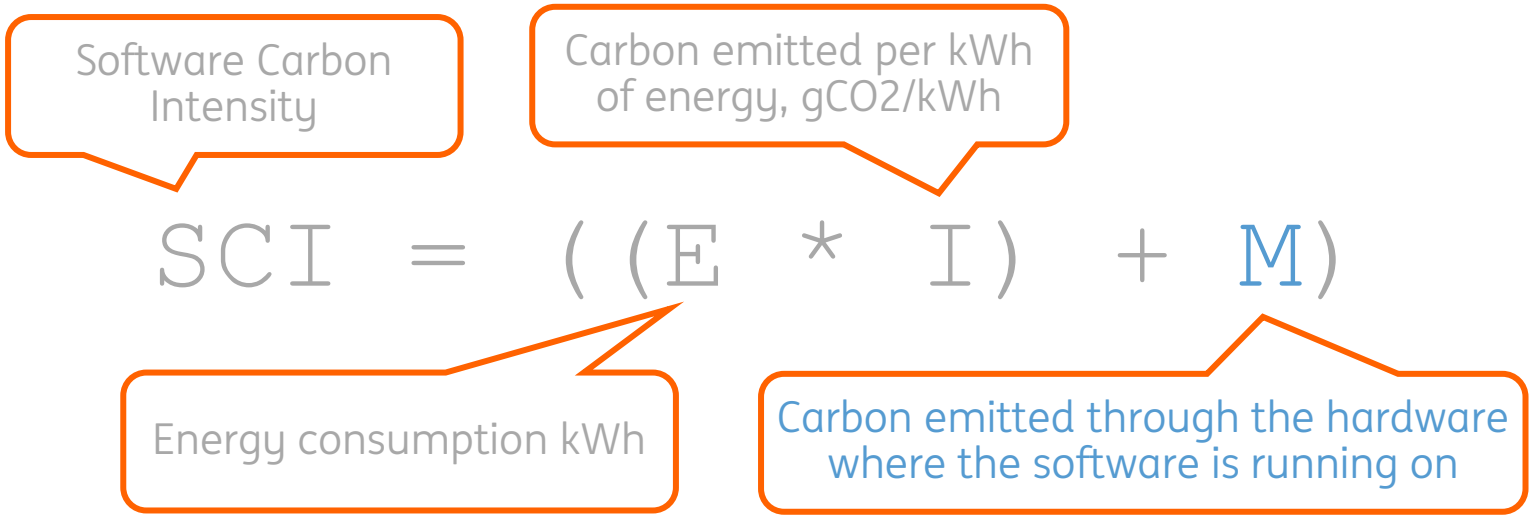
Let's introduce a formula to measure Software Carbon Intensity:



Measuring carbon emission for software

Green Software Foundation

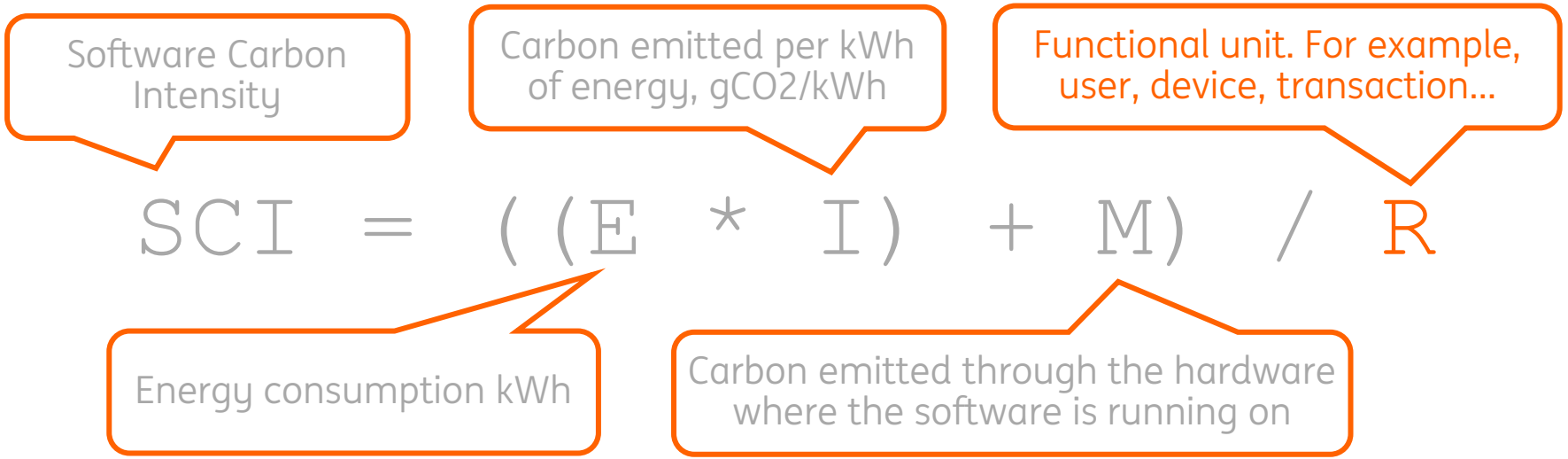
Let's introduce a formula to measure Software Carbon Intensity:



Measuring carbon emission for software

Green Software Foundation

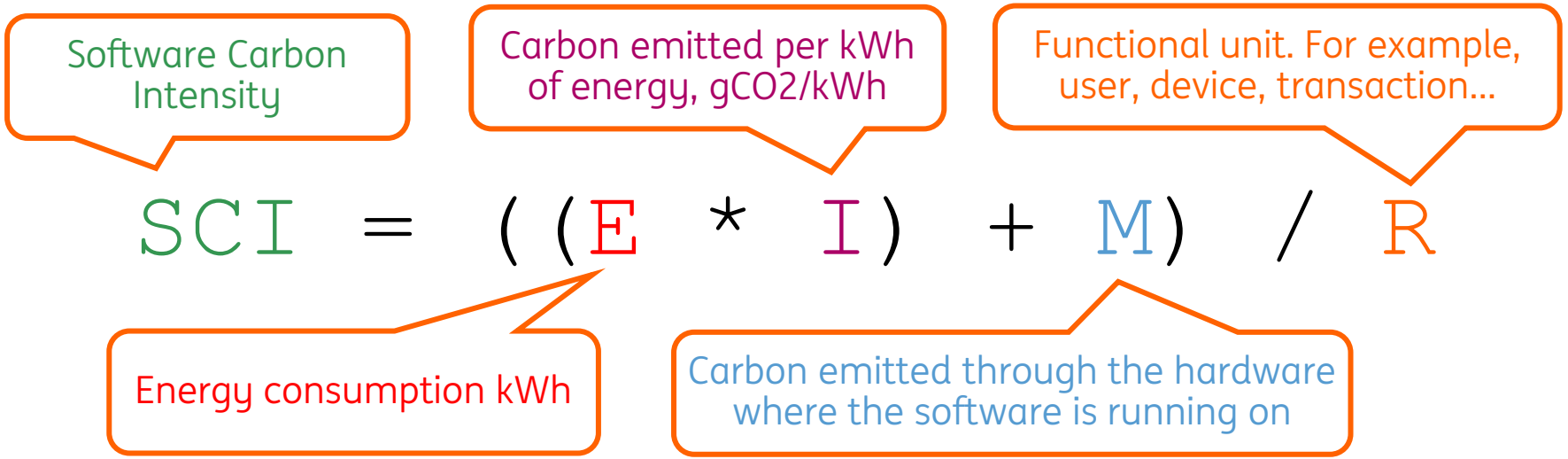
Let's introduce a formula to measure Software Carbon Intensity:



Measuring carbon emission for software

Green Software Foundation

Let's introduce a formula to measure Software Carbon Intensity:



Tools to measure carbon footprint

- Cloud
  - Amazon: **Customer Carbon Footprint Tool**
  - Azure: **Microsoft Emissions Impact Dashboard**
  - Google Cloud: **Carbon Footprint**
  - Multiplatform: **Cloud Carbon Footprint**
- Code based
  - Java: **JoularJX**
  - Android: **ecoCode**
  - Python: **codecarbon.io**
- Web
  - **Websitecarbon.com**

Agenda

- Key concepts
- Software carbon intensity
- Green patterns & good practices
  - Demand shifting
  - Storage
  - Performance improvements in code
- Conclusions

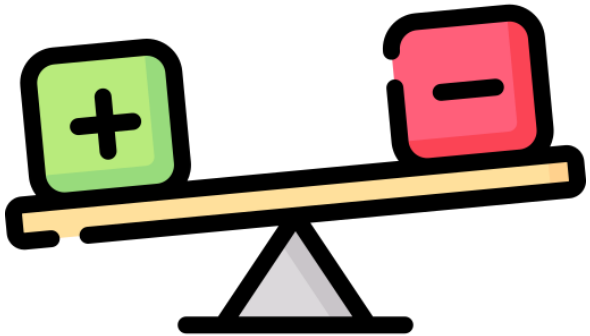
Demand shifting

- Reducing carbon intensity for your application
- Types
  - Spatial shifting
  - Temporal shifting

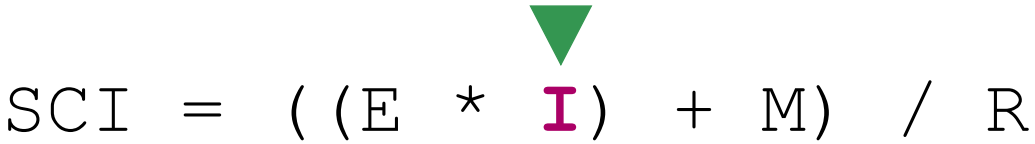
Spatial shifting

Trade-offs

- Privacy & security
- Carbon footprint & carbon intensity
- Latency



Spatial shifting – SCI impact

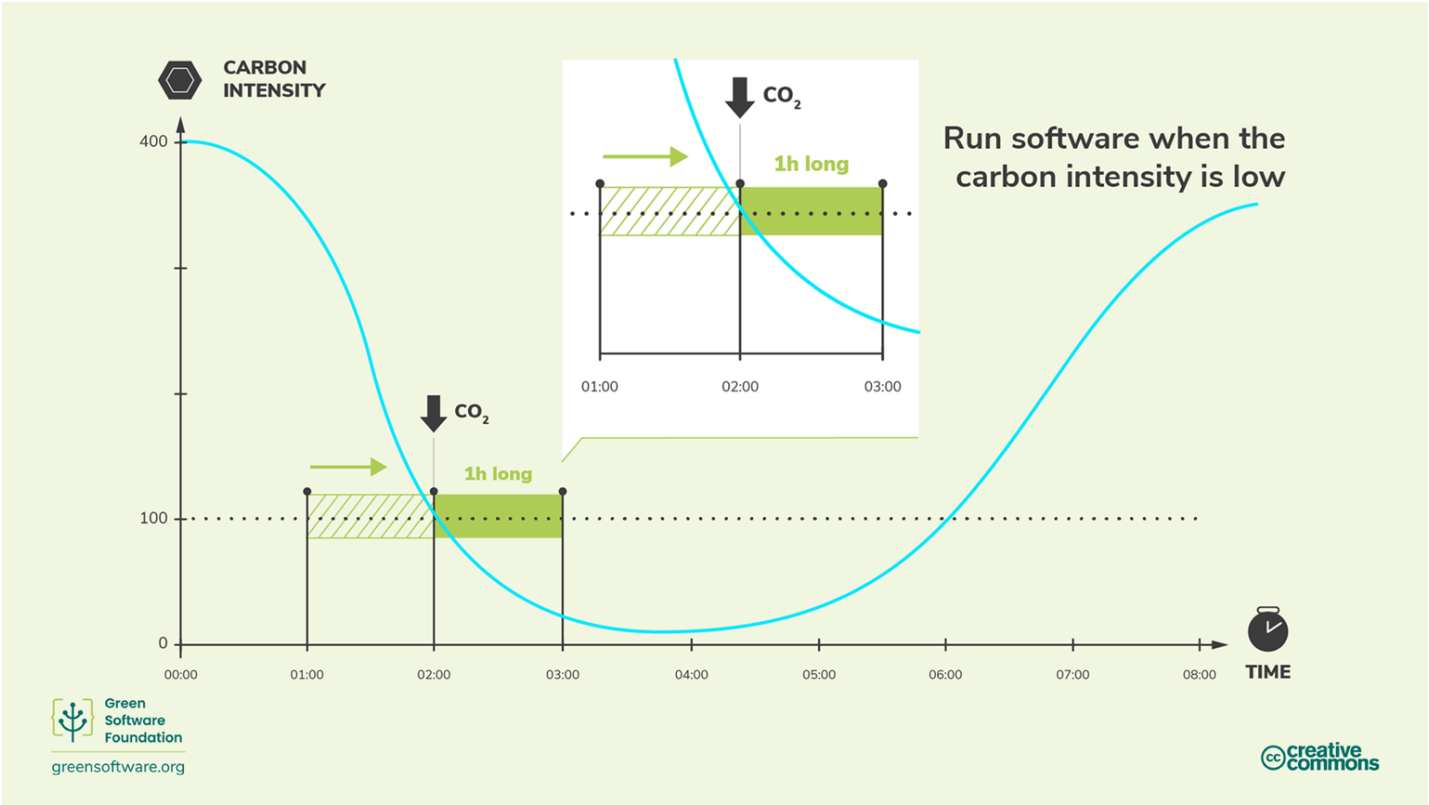


Spatial shifting – SCI impact

$$SCI = ((E * \mathbf{I}) + M) / R$$

Using a lower carbon intensity region would reduce the carbon intensity

Temporal shifting



Time-shift recurrent jobs

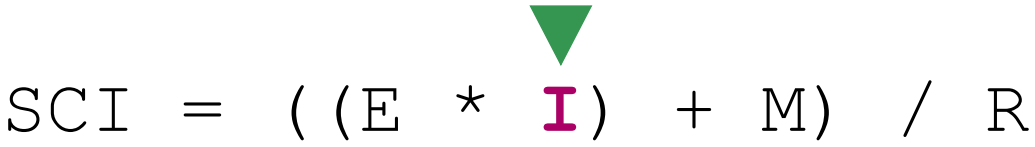
- Time shift recurrent jobs
  - Batches
  - Queue non-urgent requests
  - ML training jobs
  - OS Updates [1]
  - …
- Use carbon aware time scheduling [2]

* Google Carbon Aware Data Centers
[1] Windows 11 is now carbon aware
[2] Forecast carbon intensity

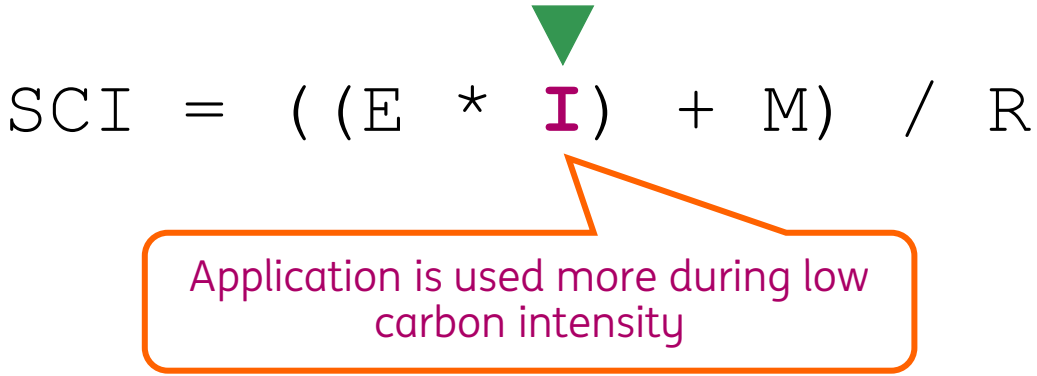
Time-shift – Suggestion

Provide green/eco mode option to your users:

Time-shift recurrent jobs – SCI Impact



Time-shift recurrent jobs – SCI Impact



Agenda

- Key concepts
- Software carbon intensity
- Green patterns & good practices
  - Demand shifting
  - Storage
  - Performance improvements in code
- Conclusions

Delete unused data

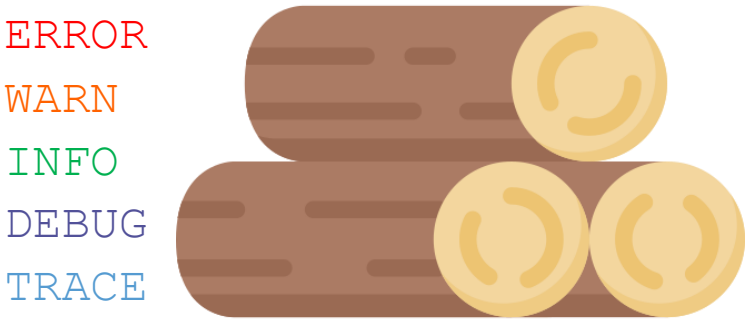
- Set storage retention policies (Automatically delete unneeded data)

Delete unused data

- Set storage retention policies (Automatically delete unneeded data)
- Keep only artifacts that are needed

Delete unused data

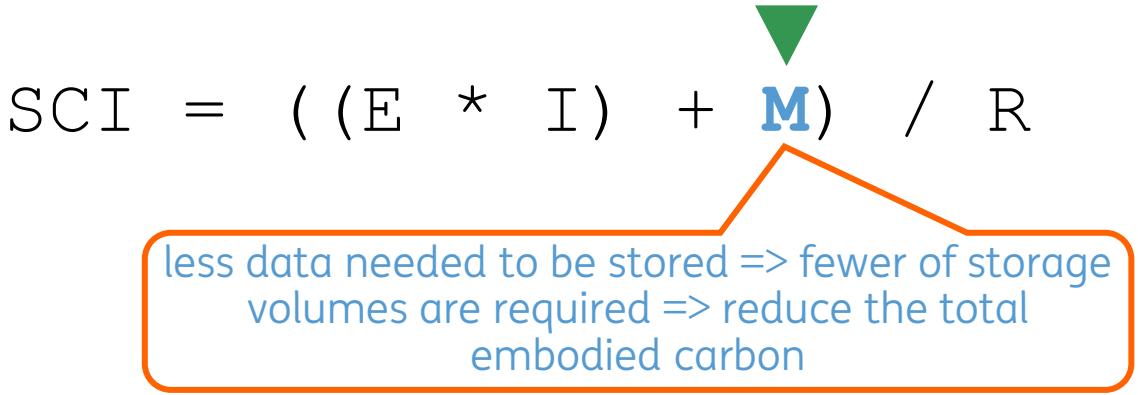
- Set storage retention policies (Automatically delete unneeded data)
- Keep only artifacts that are needed
- Set appropriate log levels
- ...



Delete unused data - SCI impact

$$SCI = ((E * I) + M) / R$$

Delete unused data - SCI impact



Be efficient with files

- Use efficient data formats
  - CSV → Parquet

Size comparison

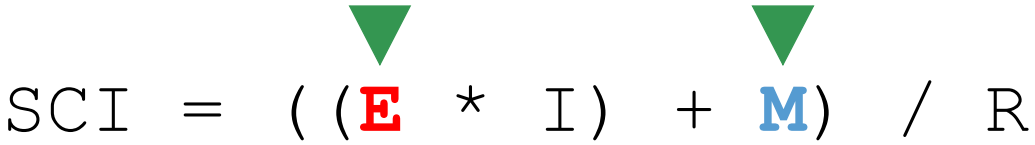
> Sizes might be slightly different in Linux and Windows

File	csv	.7z from .csv	.parquet	.7z from .parquet
fhv_tripdata_2022-01	70,8 MB	8,4 MB	11,7 MB	11,7 MB
green_tripdata_2022-01	6,6 MB	0,8359 MB	1,3 MB	1,2 MB
yellow_tripdata_2022-01	257,6 MB	31,1 MB	38,1 MB	38,3 MB

Be efficient with files

- Use efficient file formats
  - XML → Protobuf
  - gif → mp4
  - jpeg → webp
  - Consider svg
- Optimize image sizes

Be efficient with files – SCI Impact

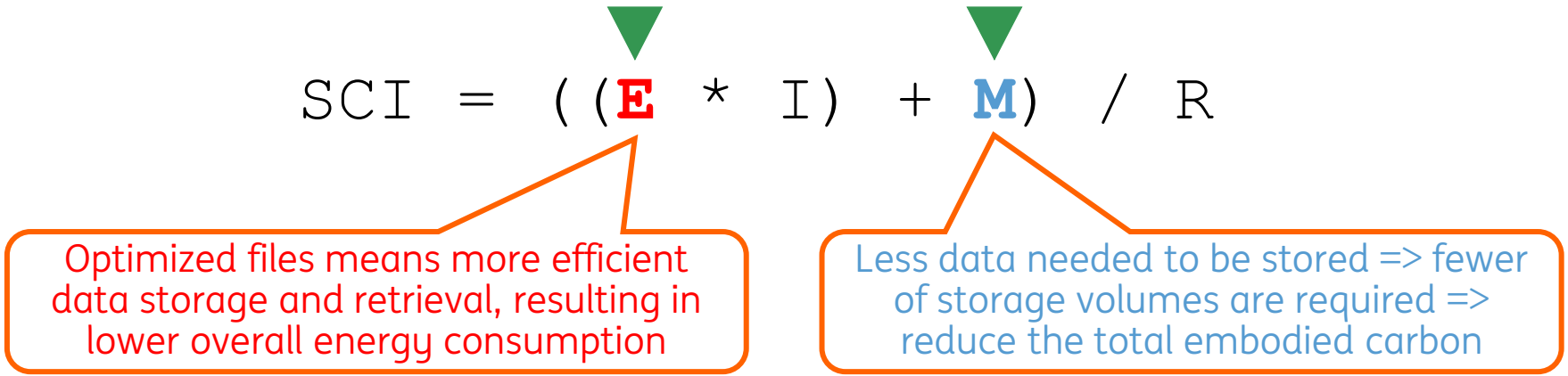


Be efficient with files – SCI Impact

$$SCI = ((E * I) + M) / R$$

Optimized files means more efficient data storage and retrieval, resulting in lower overall energy consumption

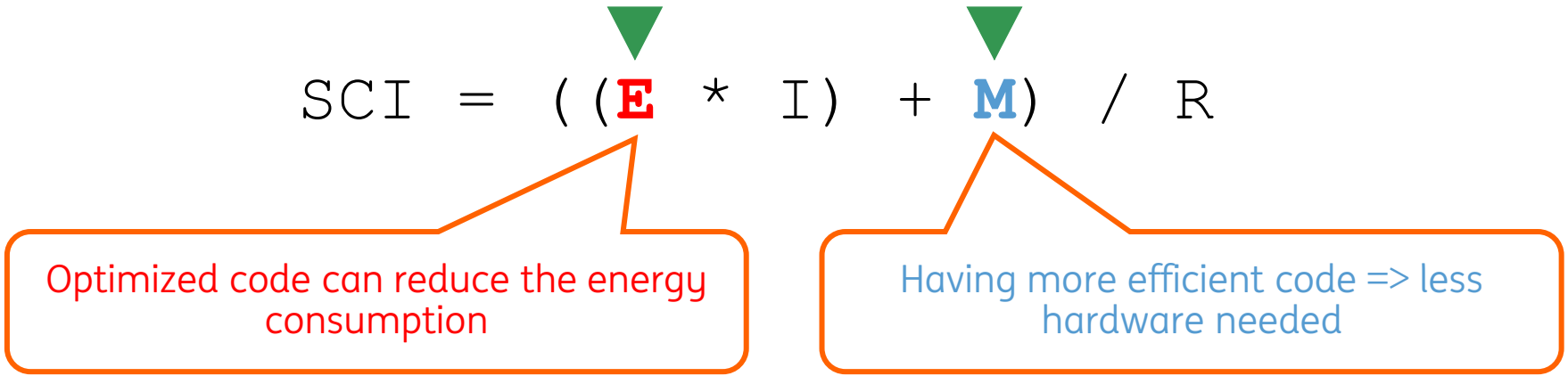
Be efficient with files – SCI Impact



Agenda

- Key concepts
- Software carbon intensity
- Green patterns & good practices
  - Demand shifting
  - Storage
  - Performance improvements in code
- Conclusions

Performance improvement in code – SCI Impact



Performance improvements in code

- Our setup
- Loading data
- Pre-allocate the right collection size
- Use SQL instead of cursors
- Hibernate
- Regex validation
- Stream
- StringBuilder

Our setup

- Epsilon GC
- Fixed CPU frequency
- Intellij profiler
- Joularjx
- PostgreSQL on Docker

Performance improvements in code

- Our setup
- Loading data
- Pre-allocate the right collection size
- Use SQL instead of cursors
- Hibernate
- Regex validation
- Stream
- StringBuilder

Performance improvements in code

- Our setup
- Loading data
- Pre-allocate the right collection size
- Use SQL instead of cursors
- Hibernate
- Regex validation
- Stream
- StringBuilder

Performance improvements in code

- Our setup
- Loading data
- Pre-allocate the right collection size
- Use SQL instead of cursors
- Hibernate
- Regex validation
- Stream
- StringBuilder

Performance improvements in code

- Our setup
- Loading data
- Pre-allocate the right collection size
- Use SQL instead of cursors
- Hibernate
- Regex validation
- Stream
- StringBuilder

Performance improvements in code

- Our setup
- Loading data
- Pre-allocate the right collection size
- Use SQL instead of cursors
- Hibernate
- Regex validation
- Stream
- StringBuilder

Performance improvements in code

- Our setup
- Loading data
- Pre-allocate the right collection size
- Use SQL instead of cursors
- Hibernate
- Regex validation
- Stream
- StringBuilder

Stream

```
// Find if there is a number larger than 12 in a very large list
list.stream().filter(n -> n > 12).toList().size() > 0
```

Stream

```
// Find if there is a number larger than 12 in a very large list
list.stream().filter(n -> n > 12).toList().size() > 0
!list.stream().filter(n -> n > 12).toList().isEmpty()
```

Stream

```
// Find if there is a number larger than 12 in a very large list
list.stream().filter(n -> n > 12).toList().size() > 0
!list.stream().filter(n -> n > 12).toList().isEmpty()
list.stream().filter(n -> n > 12).count() > 0
```

Stream

```
// Find if there is a number larger than 12 in a very large list
list.stream().filter(n -> n > 12).toList().size() > 0
!list.stream().filter(n -> n > 12).toList().isEmpty()
list.stream().filter(n -> n > 12).count() > 0
list.stream().anyMatch(n -> n > 12)
```

Stream

```
// Find if there is a number larger than 12 in a very large list
list.stream().filter(n -> n > 12).toList().size() > 0          // took 2059ms && 1GB allocation
!list.stream().filter(n -> n > 12).toList().isEmpty()          // took 2026ms && 1GB allocation
list.stream().filter(n -> n > 12).count() > 0                  // took 1052ms
list.stream().anyMatch(n -> n > 12)                            // took 8ms
```

Question…

- What can be improved?

```
@Path("/isAlive")
public class IsAlive {
    @GET
    @Produces(MediaType.APPLICATION_JSON)
    public StatusResponse getMessage() {
        return StatusResponse.builder().status(MonitoringStatus.OK).build();
    }
}
```

Singleton

- Use global singleton instances to create empty objects

Do you really need an equal instance in each call 🤔?

```
@Path("/isAlive")
public class IsAlive {
    @GET
    @Produces(MediaType.APPLICATION_JSON)
    public StatusResponse getMessage() {
        return StatusResponse.builder().status(MonitoringStatus.OK).build();
    }
}
```

Singleton

- Use global singleton instances to create empty objects

What about returning the same object?

```
final static StatusResponse r = StatusResponse.builder().status(MonitoringStatus.OK).build();

@Path("/isAlive")
public class IsAlive {
    @GET
    @Produces(MediaType.APPLICATION_JSON)
    public StatusResponse getMessage() {
        return r;
    }
}
```

Performance improvements in code

- Our setup
- Loading data
- Pre-allocate the right collection size
- Use SQL instead of cursors
- Hibernate
- Regex validation
- Stream
- Singletons
- StringBuilder

Agenda

- Key concepts
- Software carbon intensity
- Green patterns & good practices
  - Demand shifting
  - Storage
  - Performance improvements in code
- Conclusions

To recap

- Serious challenge ahead of us
- It’s crucial that we make a difference also in IT

To recap

- Serious challenge ahead of us
- It’s crucial that we make a difference also in IT
- Good news! Growing number of tools, resources and solutions

To recap

- Serious challenge ahead of us
- It's crucial that we make a difference also in IT
- Good news! Growing number of tools, resources and solutions

Green Software Foundation

Do you really need everything for now?

Small changes make big impact (e.g. sorting the trash)

MUNICIPAL WASTE

What is municipal waste?

It is everyday waste collected and treated by municipalities, which is mainly generated by households.

Municipal waste accounts for 27% of total waste generated in the EU

	Municipal waste generated (kg/capita - 2021)	Share of recycling and composting of municipal waste (2021)	Landfill rate of waste (excluding major mineral) (2020)
EU average	530	49.6%	18%

* According to European Parliament

Small changes make big impact (e.g. sorting the trash)

MUNICIPAL WASTE

What is municipal waste?

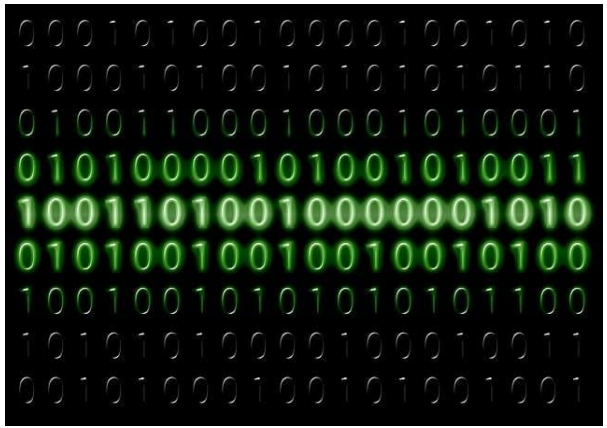
It is everyday waste collected and treated by municipalities, which is mainly generated by households.

Municipal waste accounts for 27% of total waste generated in the EU

	Municipal waste generated (kg/capita - 2021)	Share of recycling and composting of municipal waste (2021)	Landfill rate of waste (excluding major mineral) (2020)
EU average	530	49.6%	18%

* According to European Parliament

Save the planet bit by bit



Let’s keep in touch

Scan the QR code to get the presentation,
the repos and the information

We’ll see one to each other in the ING both

do your thing