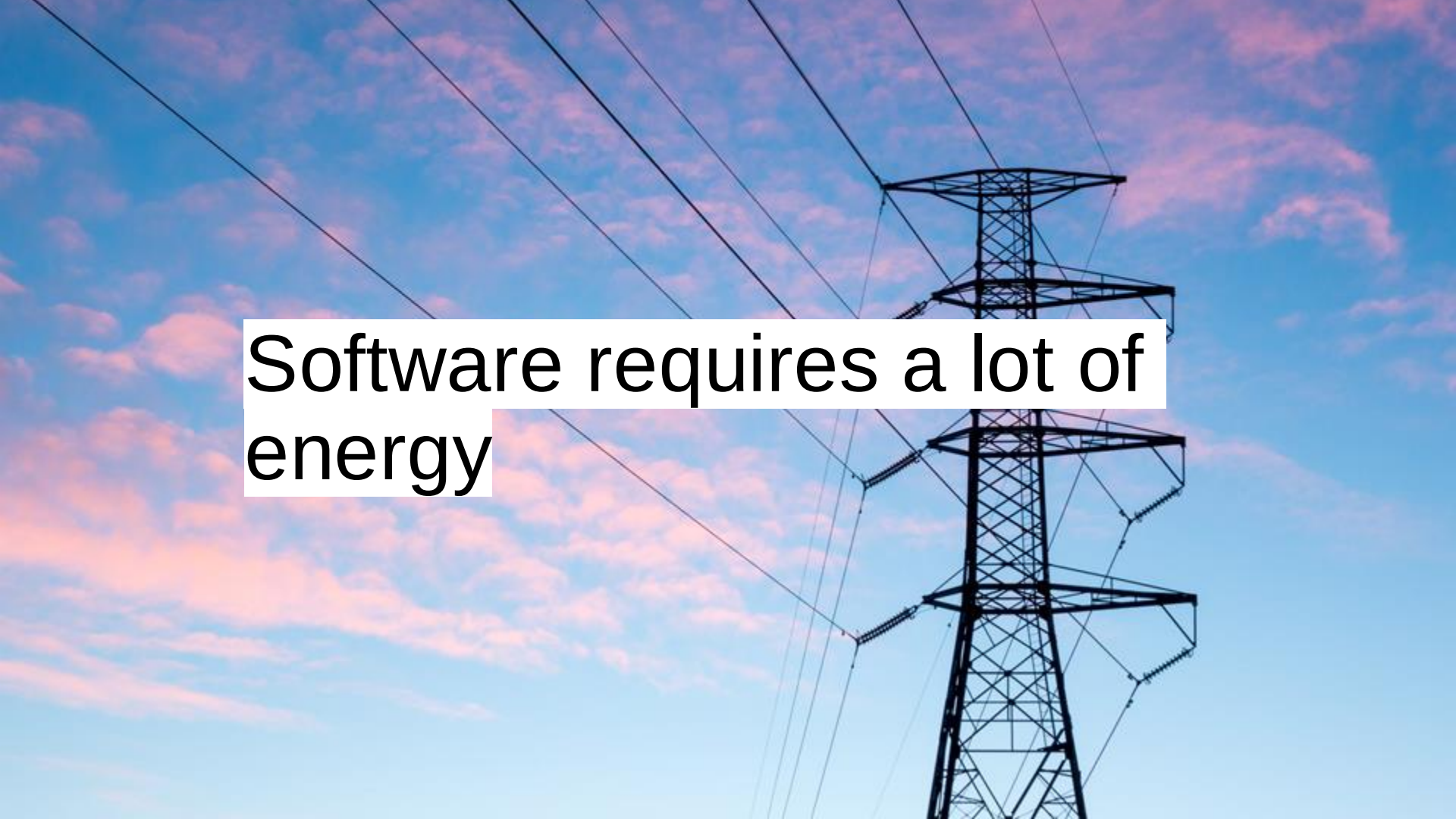
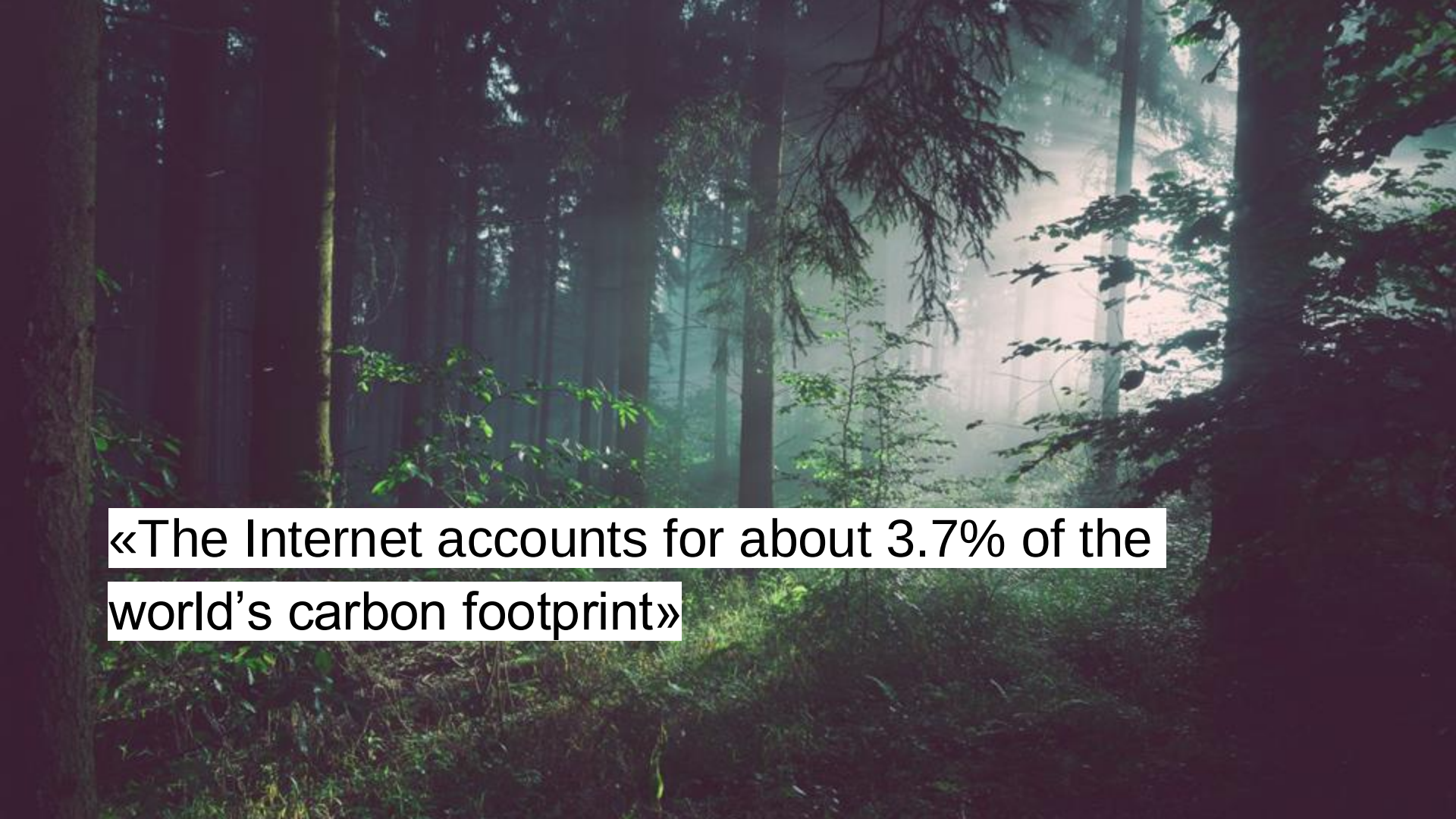
Is our software sustainable?

tietoevry


Software requires a lot of energy


«The Internet accounts for about 3.7% of the world’s carbon footprint»

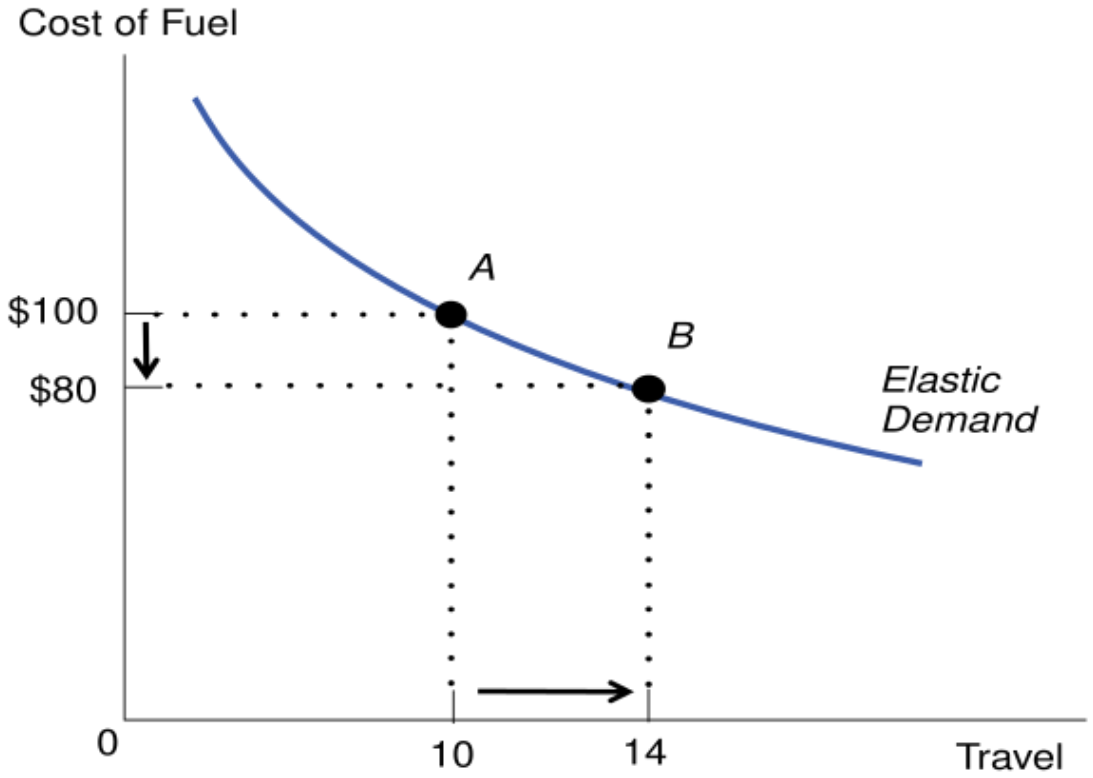
Global trends in digital and energy indicators, 2015-2021

	2015	2021	Change
Internet users	3 billion	4.9 billion	+60%
Internet traffic	0.6 ZB	3.4 ZB	+440%
Data centre workloads	180 million	650 million	+260%
Data centre energy use (excluding crypto)	200 TWh	220-320 TWh	+10-60%
Crypto mining energy use	4 TWh	100-140 TWh	+2 300-3 300%
Data transmission network energy use	220 TWh	260-340 TWh	+20-60%

Sources: Internet users [ITU (2022)]; internet traffic [IEA analysis based on Cisco (2015); TeleGeography (2022); Cisco (2019), Cisco Visual Networking Index]; data centre workloads [Cisco (2018), Cisco Global Cloud Index]; data centre energy use [IEA analysis based on Malmodin & Lundén (2018); ITU (2020); Masanet et al. (2020); Malmodin (2020); Hintemann & Hinterholzer (2022)]; cryptocurrency mining energy use [IEA analysis based on Cambridge Centre for Alternative Finance (2022); Gallersdörfer, Klaaßen and Stoll (2020); McDonald (2022)]; data transmission network energy use [Malmodin & Lundén (2018); Malmodin (2020); ITU (2020); Coroama (2021); GSMA (2022)].

Jevons Paradox

The effect where efficiency gains translate to increased demand and increased total resource use.



NATIONAL

Three Mile Island nuclear plant will reopen to power Microsoft data centers

SEPTEMBER 20, 2024 · 1:40 PM ET

By C Mandler

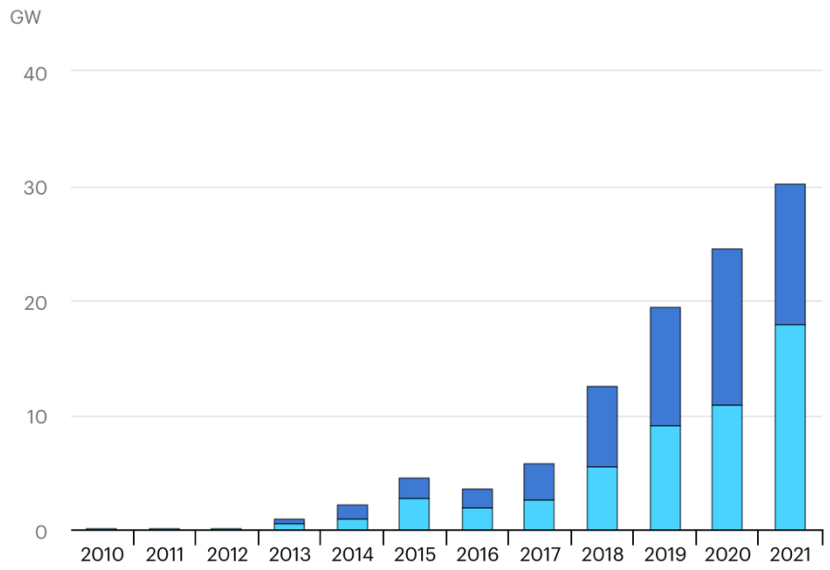
The Three Mile Island nuclear plant is seen in March 2011 in Middletown, Pa.

Jeff Fusco/Getty Images

Source: npr.org

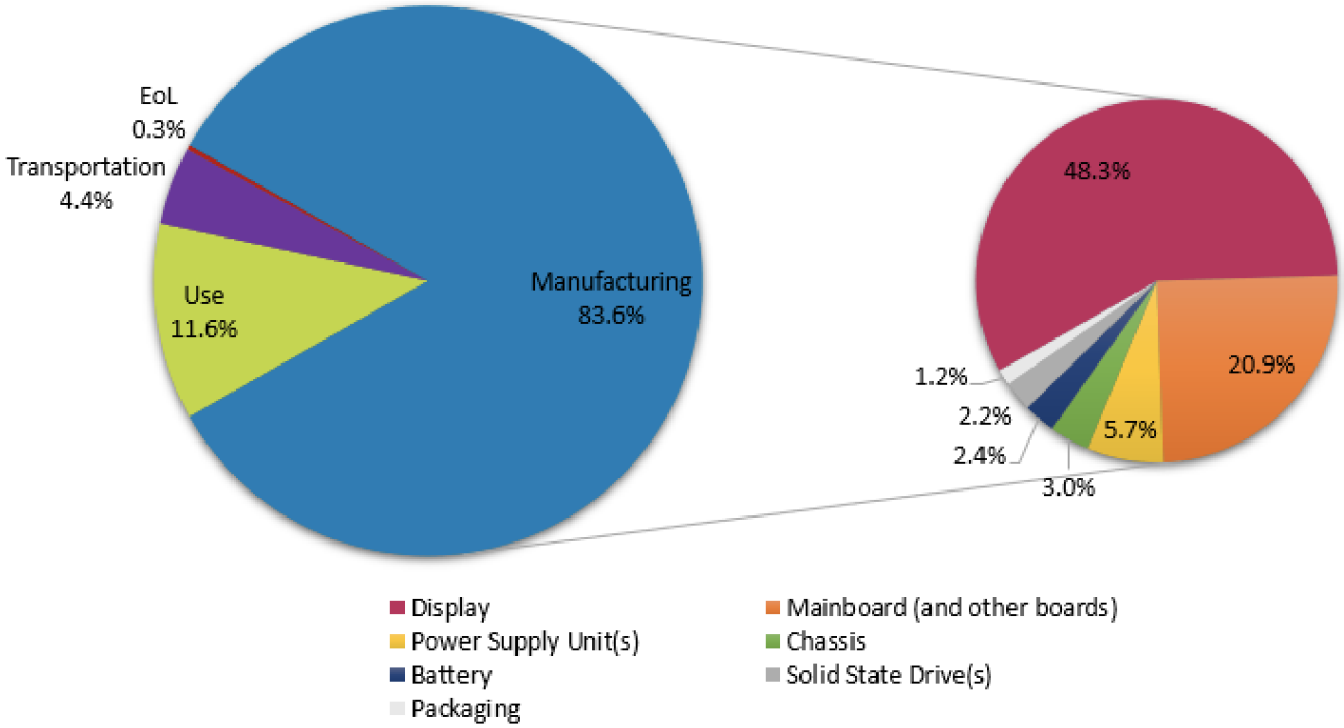
Global renewable energy power purchase agreements by sector, 2010-2021

Open



IEA. Licence: CC BY 4.0

ICT sector Other sectors


EoL
0.3%
Transportation
4.4%
Use
11.6%
Manufacturing
83.6%
48.3%
20.9%
5.7%
3.0%
2.4%
2.2%
1.2%
Display
Mainboard (and other boards)
Power Supply Unit(s)
Chassis
Battery
Solid State Drive(s)
Packaging

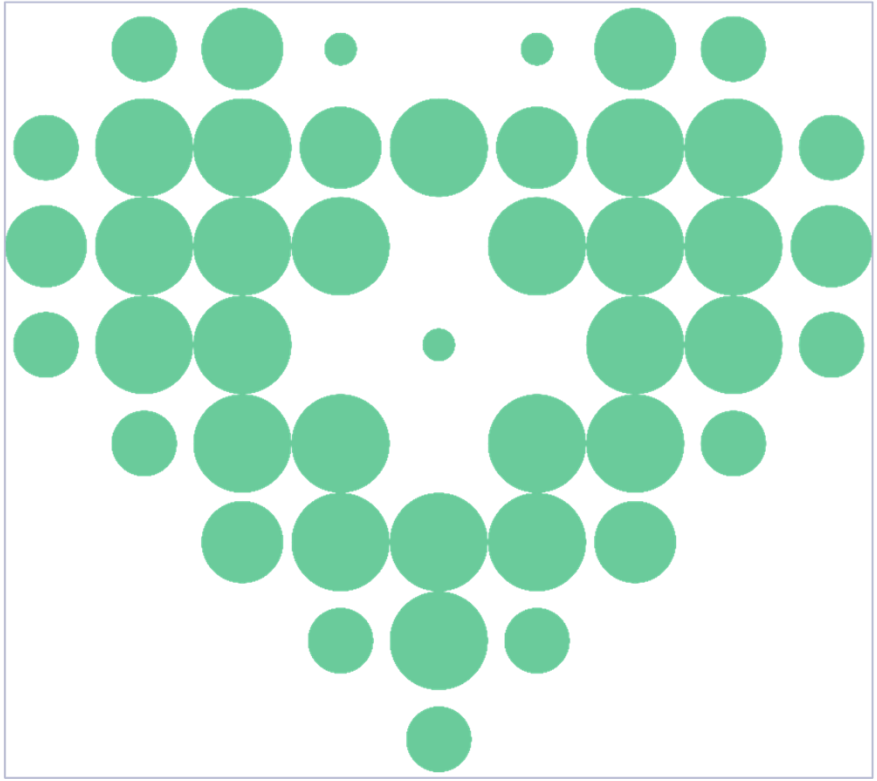
Why Worry About Software Emission

IT consumes a lot of energy

Industries face growing demand for ”greenness”

Competitive advantage

Reporting requirements and compliance



About me

Kent Inge Fagerland Simonsen

- About 20 years of software engineering
- PhD in Software Engineering from DTU
- Consultant, Coder, etc @ Tietoevry Create
- Advocating for sustainable software practices for about two years

Handprint

Handprint vs Footprint

Handprint increase

- Reduce carbon footprint of other activity
- Positive impact on climate
- Impact should exceed cost
- Highest potential (probably)

Footprint reduction

- Reduce carbon footprint of current activity
- Positive impact on climate
- Direct impact

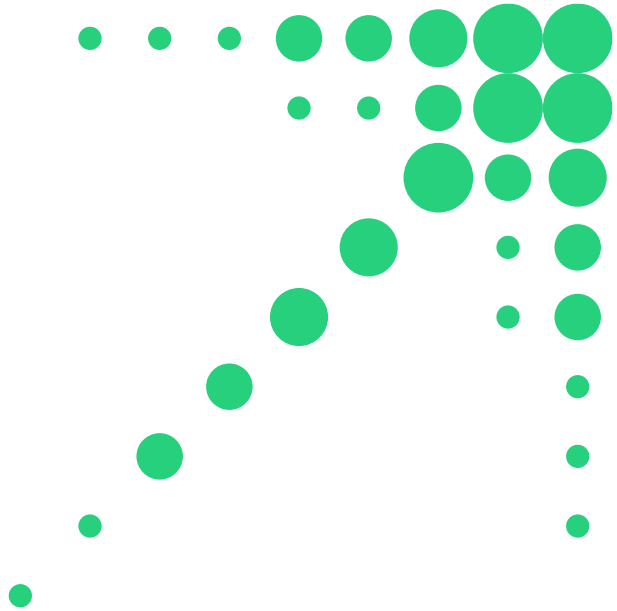
Handprint: Example Teams

How much does a video call actually save

- one trip DUB-LHR = 176kgCO2e
- 1 hour video call streaming cost 0,150kgCO2e
- (176*2) / 0,15 = 2347 attendees before flying to an in-person meeting is preferable.

Handprint: In BSD

- Efficient software causes less energy use
- Prolong lifetime of hardware
- ……

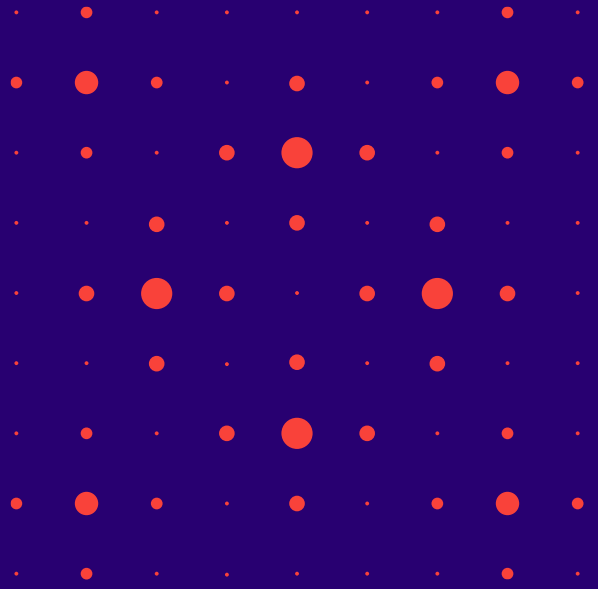


Handprint: Carbon Negative Software

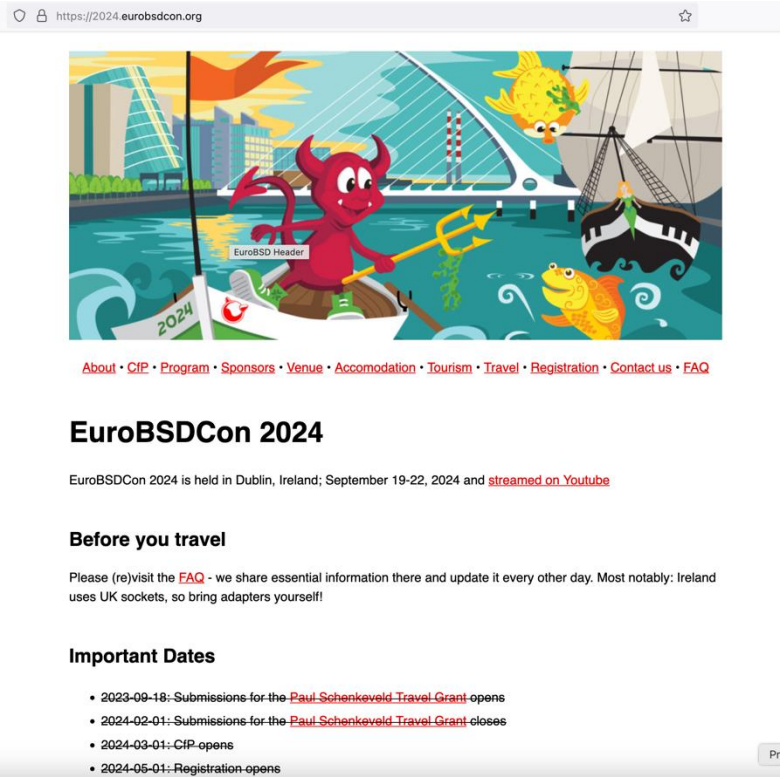
Handprint – Footprint > 0

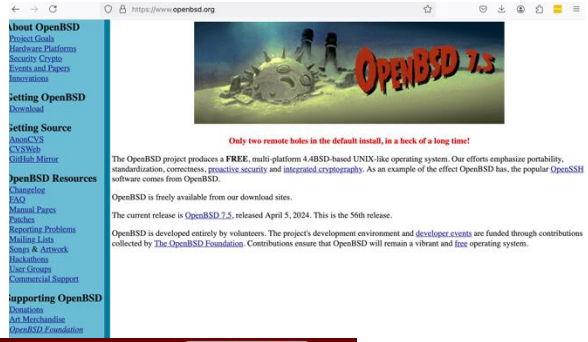
Footprint

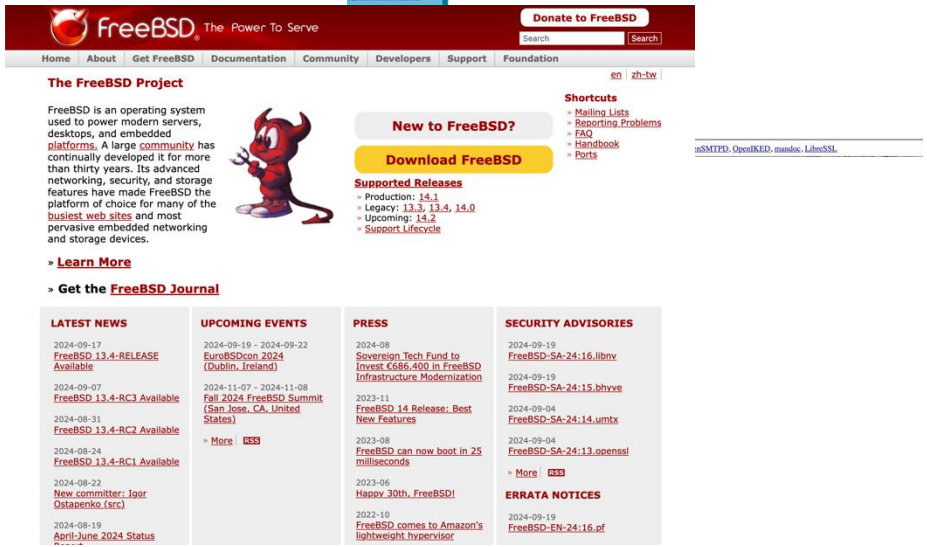
Web Sustainability



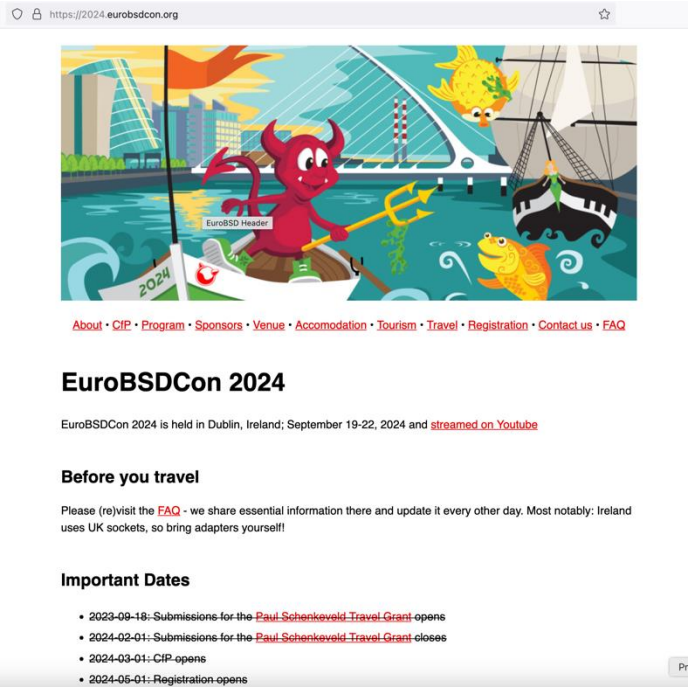
Concerning Websites

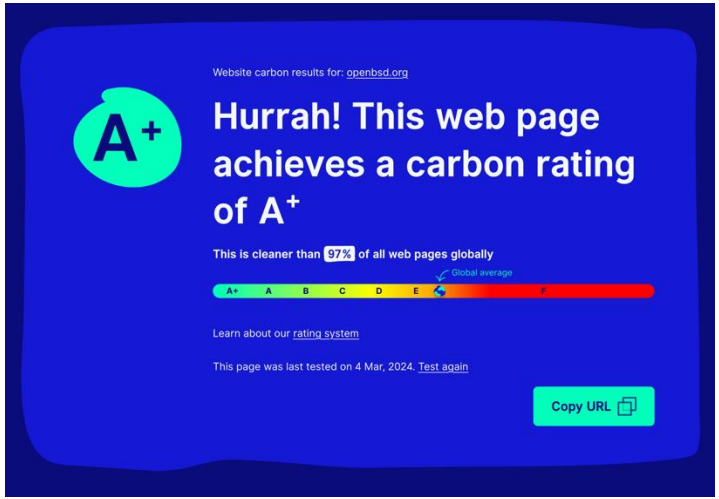


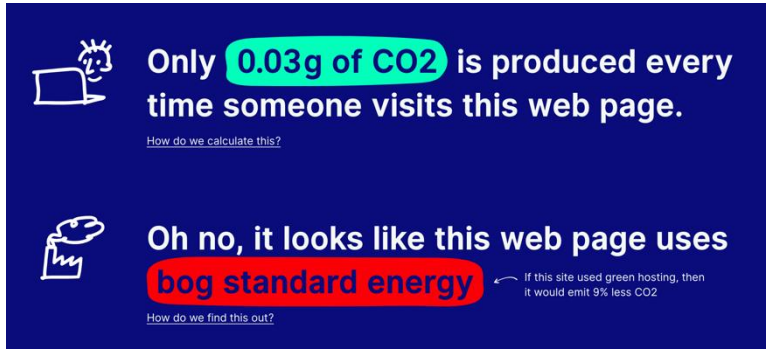




BSD Web Results







www.websitecarbon.com

Battle of the BSD Websites

BSD	Frontpage emissions per view (gCO2e)
netbsd.org	0,01
freebsd.org	0,02
openbsd.org	0,03

About OpenBSD
- Project Goals
- Hardware Platforms
- Security Crypto
- Events and Papers
- Innovations

Getting OpenBSD
- Download

Getting Source
- AnonCVS
- CVSWeb
- GitHub Mirror

OpenBSD Resources
- Changelog
- FAQ
- Manual Pages
- Patches
- Reporting Problems
- Mailing Lists
- Songs & Artwork
- Hackathons
- User Groups
- Commercial Support

Supporting OpenBSD
- Donations
- Art Merchandise
- *OpenBSD Foundation*

Only two remote holes in the default install, in a heck of a long time!

The OpenBSD project produces a **FREE**, multi-platform 4.4BSD-based UNIX-like operating system. Our efforts emphasize portability, standardization, correctness, proactive security and integrated cryptography. As an example of the effect OpenBSD has, the popular OpenSSH software comes from OpenBSD.

OpenBSD is freely available from our download sites.

The current release is OpenBSD 7.5, released April 5, 2024. This is the 56th release.

OpenBSD is developed entirely by volunteers. The project's development environment and developer events are funded through contributions collected by The OpenBSD Foundation. Contributions ensure that OpenBSD will remain a vibrant and free operating system.

Associated projects: OpenSSH, OpenBGPD, rpki-client, OpenNTPD, OpenSMTPD, OpenIKED, mandoc, LibreSSL

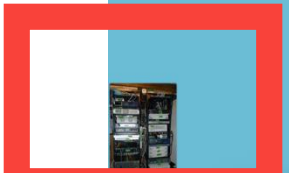
About OpenBSD
- Project Goals
- Hardware Platforms
- Security Crypto
- Events and Papers
- Innovations

Getting OpenBSD
- Download

Getting Source
- AnonCVS
- CVSWeb
- GitHub Mirror

OpenBSD Resources
- Changelog
- FAQ
- Manual Pages
- Patches
- Reporting Problems
- Mailing Lists
- Songs & Artwork
- Hackathons
- User Groups
- Commercial Support

Supporting OpenBSD
- Donations
- Art Merchandise
- *OpenBSD Foundation*



Only two remote holes in the default install, in a heck of a long time!

The OpenBSD project produces a **FREE**, multi-platform 4.4BSD-based UNIX-like operating system. Our efforts emphasize portability, standardization, correctness, proactive security and integrated cryptography. As an example of the effect OpenBSD has, the popular OpenSSH software comes from OpenBSD.

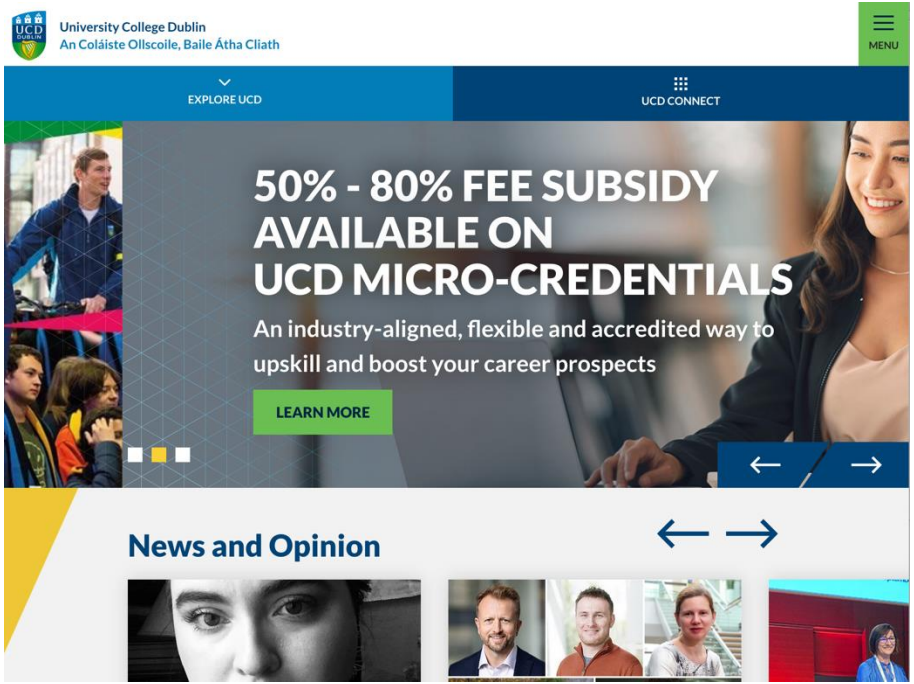
OpenBSD is freely available from our download sites.

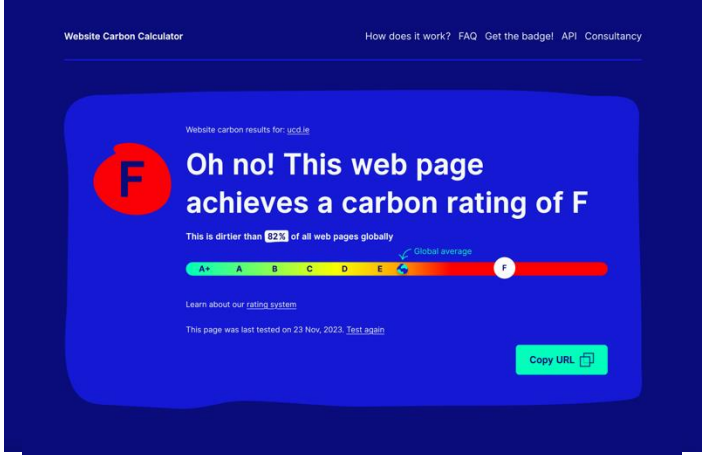
The current release is OpenBSD 7.5, released April 5, 2024. This is the 56th release.

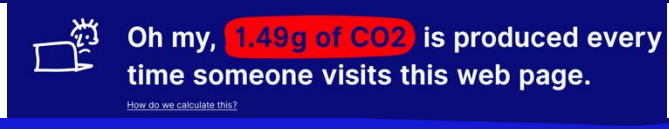
OpenBSD is developed entirely by volunteers. The project's development environment and developer events are funded through contributions collected by The OpenBSD Foundation. Contributions ensure that OpenBSD will remain a vibrant and free operating system.

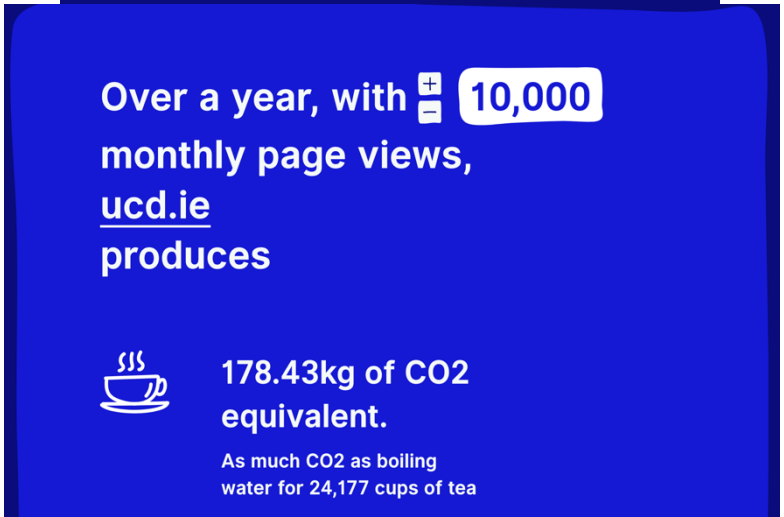
Associated projects: OpenSSH, OpenBGPD, rpki-client, OpenNTPD, OpenSMTPD, OpenIKED, mandoc, LibreSSL

Are websites even that big?


University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath
MENU
EXPLORE UCD
UCD CONNECT
50% - 80% FEE SUBSIDY AVAILABLE ON UCD MICRO-CREDENTIALS
An industry-aligned, flexible and accredited way to upskill and boost your career prospects
LEARN MORE
News and Opinion


Website Carbon Calculator
How does it work? FAQ Get the badge! API Consultancy
Website carbon results for: ucd.ie
F
Oh no! This web page achieves a carbon rating of F
This is dirtier than 82% of all web pages globally
Global average
A+ A B C D E F
Learn about our rating system
This page was last tested on 23 Nov, 2023. Test again
Copy URL

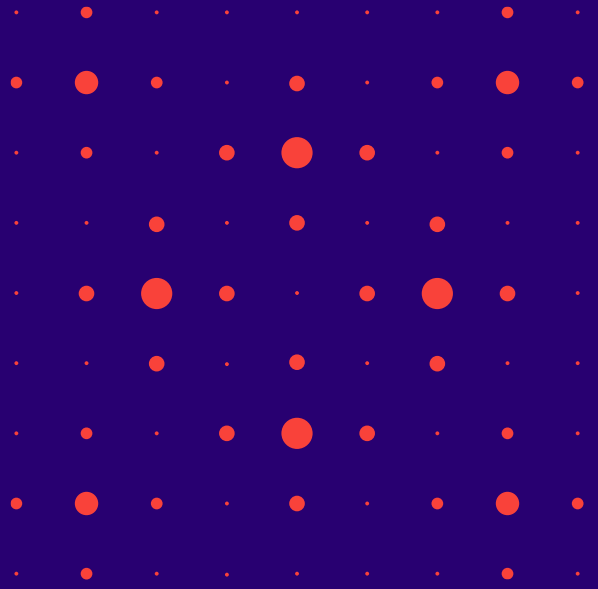

Oh my, 1.49g of CO2 is produced every time someone visits this web page.
How do we calculate this?


Over a year, with 10,000 monthly page views, ucd.ie produces
178.43kg of CO2 equivalent.
As much CO2 as boiling water for 24,177 cups of tea

What to do?

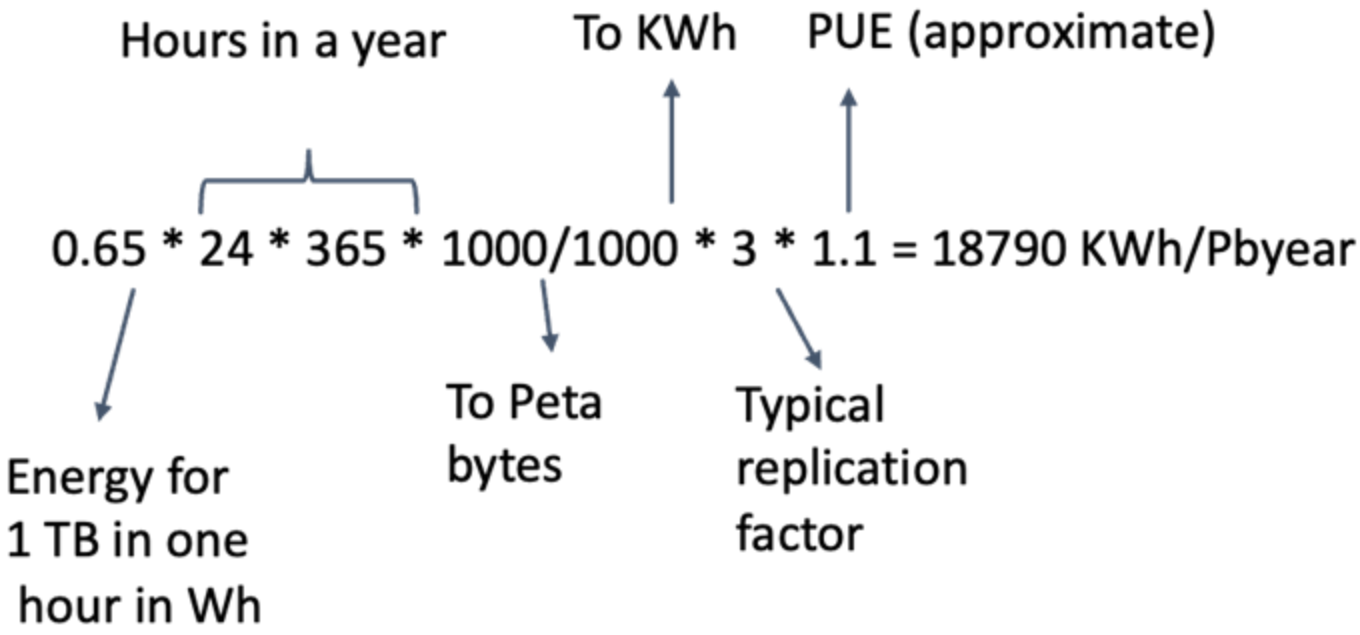
- Green Hosting
- Compress data
- Optimize image size and format
- Careful with video
- Keep unused elements out of DOM, CSS..

Data



Data; the new gold?
..or was it coal?

Energy requirement for storage of 1PB for 1 year :



JSON (68 characters)

```
{
  "id": 1234,
  "name": "John Doe",
  "email": "johndoe@example.com",
  "age": 30
}
```

XML (98 characters)

```
<person>
  <id>1234</id>
  <name>John Doe</name>

<email>johndoe@example.com</email>
  <age>30</age>
</person>
```

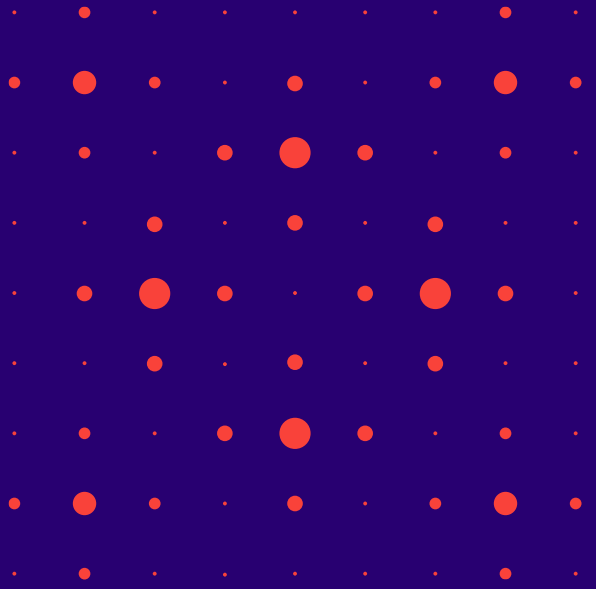
Protobuf (37 bytes)

```
0A 04 D2 09 0A 08 4A 6F 68 6E 20
44 6F 65 12 13 6A 6F 68 6E 64 6F
65 40 65 78 61 6D 70 6C 65 2E 63
6F 6D 18 1E
```

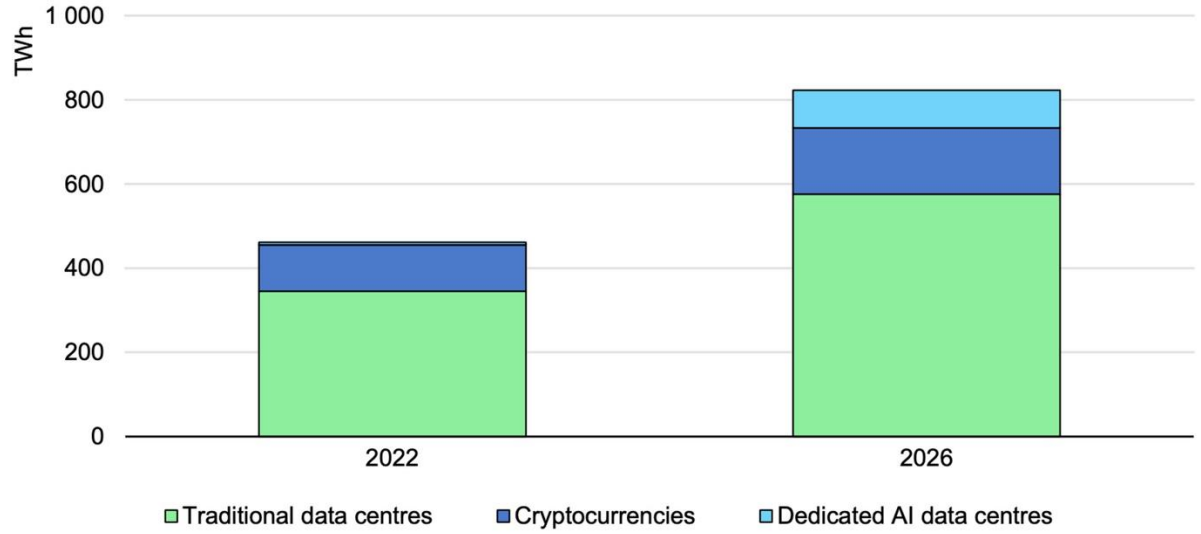
CSV (36 characters)

```
1234,John Doe,johndoe@example.com,30
```

Cloud & Waste



Estimated electricity demand from traditional data centres, dedicated AI data centres and cryptocurrencies, 2022 and 2026, base case

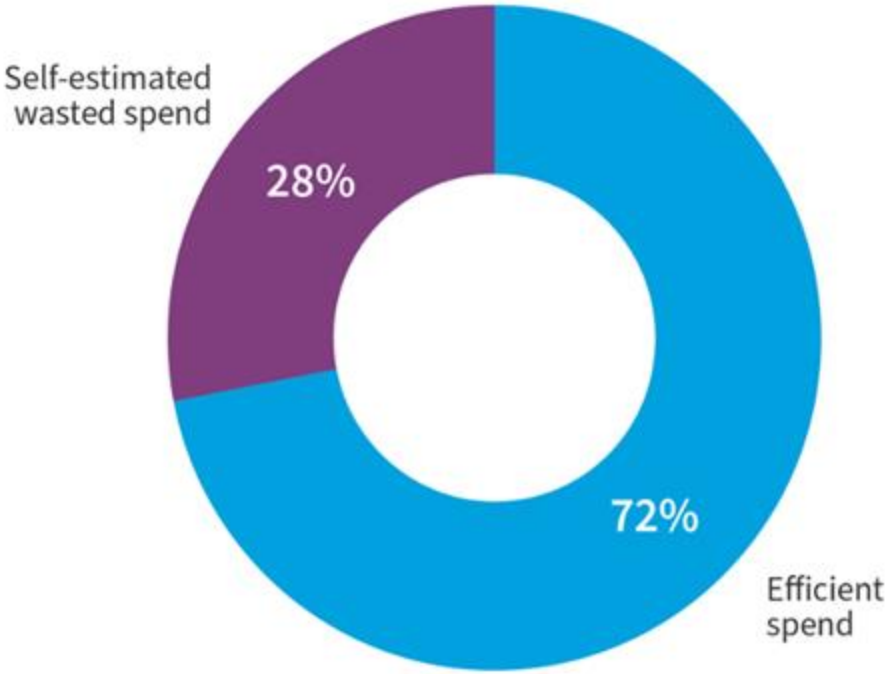


IEA. CC BY 4.0.

Note: Data centre electricity demand excludes consumption from data network centres.

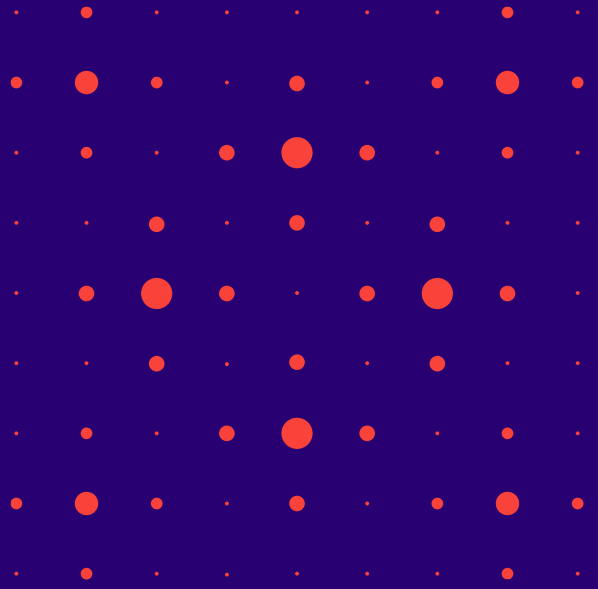
Sources: IEA forecast based on data and projections from Data Centres and Data Transmission Networks; Joule (2023), Alex de Vries, The growing energy footprint of artificial intelligence; Crypto Carbon Ratings Institute, Indices; Ireland Central Statistics Office, Data Centres Metered Electricity Consumption 2022; and Danish Energy Agency, Denmark's Energy and Climate Outlook 2018.

What's your estimated wasted cloud spend?



N=750
Source: Flexera 2023 State of the Cloud Report
flexera

Open Source & Containers

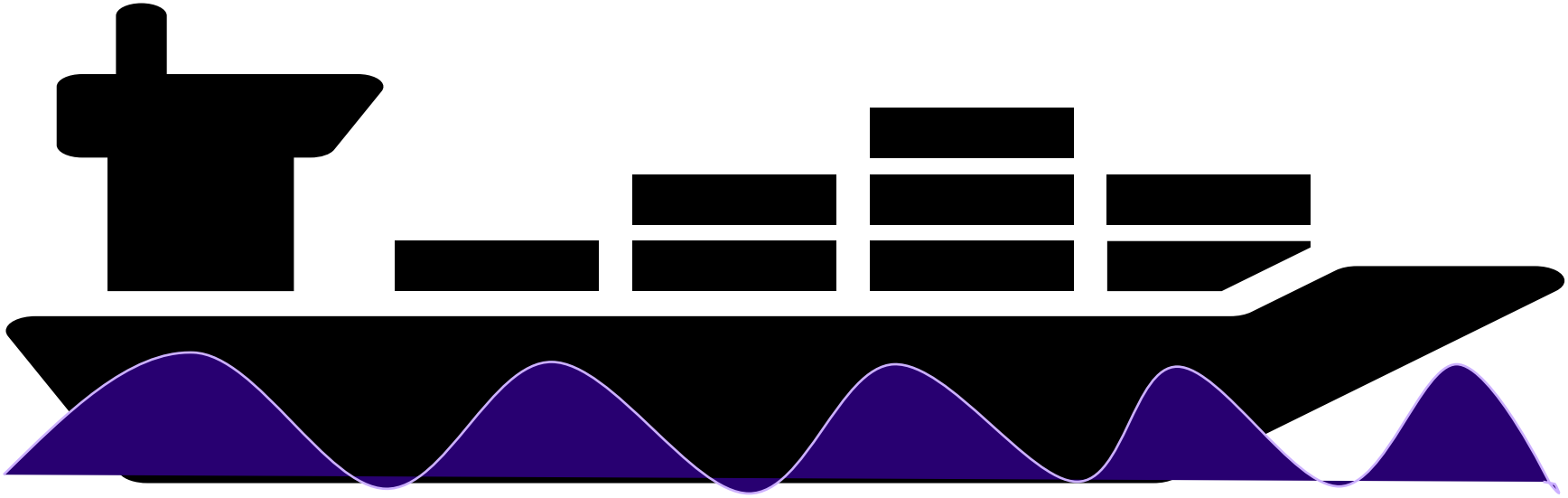


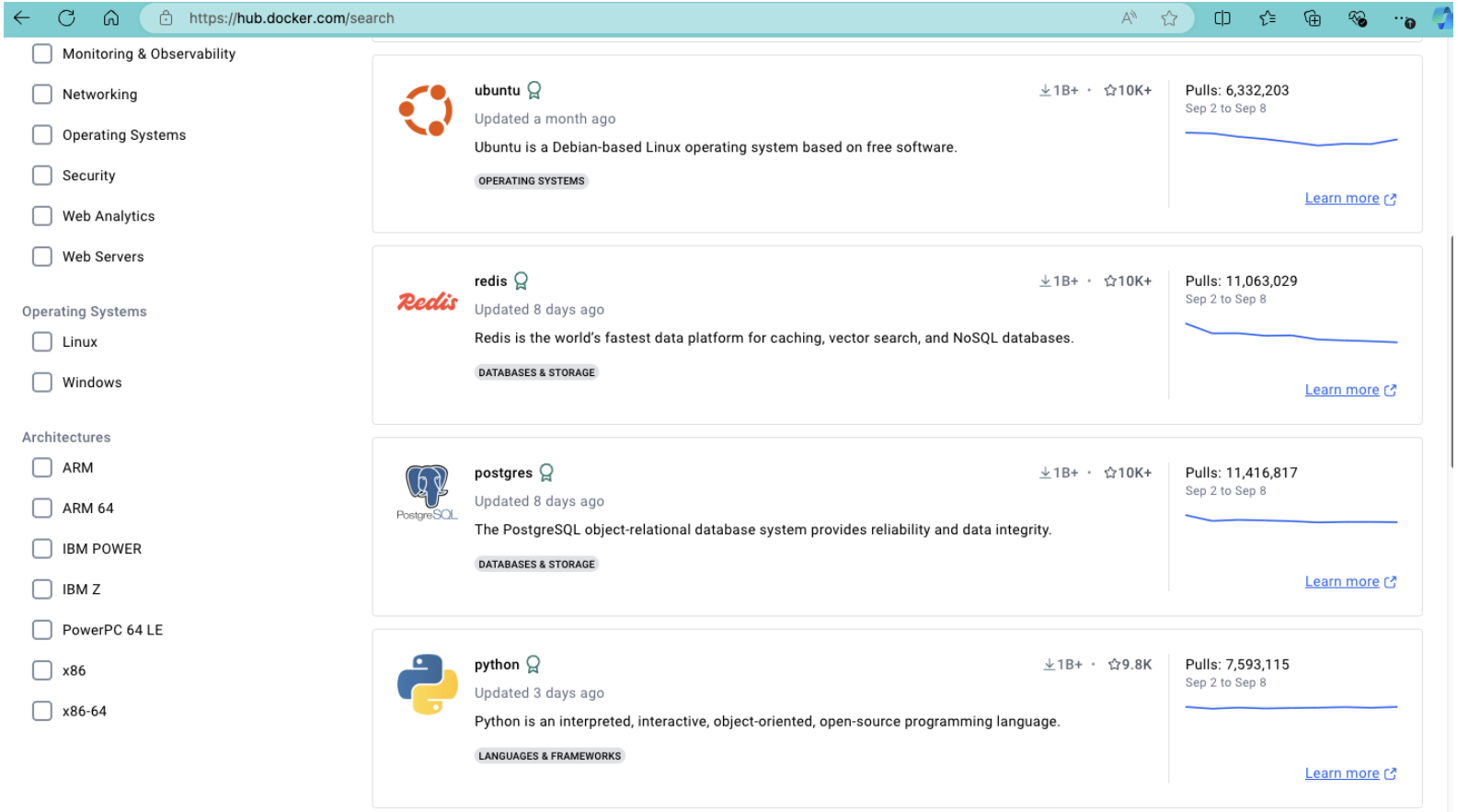
Imagined example

- Software installed on 1B devices
- Used a singe J (Wh) more than necessary per day per device (on average)
- 1GWh of extra power use per day
- 365 GWh per year
- Emissions similar to ~1.000 short airplane trips

- Now: imagine that there are hundreds of such projects

Concerning Containers




https://hub.docker.com/search
Monitoring & Observability
Networking
Operating Systems
Security
Web Analytics
Web Servers
Operating Systems
Linux
Windows
Architectures
ARM
ARM 64
IBM POWER
IBM Z
PowerPC 64 LE
x86
x86-64
ubuntu
Updated a month ago
Ubuntu is a Debian-based Linux operating system based on free software.
OPERATING SYSTEMS
1B+ · 10K+
Pulls: 6,332,203
Sep 2 to Sep 8
Learn more
redis
Updated 8 days ago
Redis is the world's fastest data platform for caching, vector search, and NoSQL databases.
DATABASES & STORAGE
1B+ · 10K+
Pulls: 11,063,029
Sep 2 to Sep 8
Learn more
postgres
Updated 8 days ago
The PostgreSQL object-relational database system provides reliability and data integrity.
DATABASES & STORAGE
1B+ · 10K+
Pulls: 11,416,817
Sep 2 to Sep 8
Learn more
python
Updated 3 days ago
Python is an interpreted, interactive, object-oriented, open-source programming language.
LANGUAGES & FRAMEWORKS
1B+ · 9.8K
Pulls: 7,593,115
Sep 2 to Sep 8
Learn more

Network: kWh/GB	**0,059**
Co2 factor g/kWh	**481**
Bytes	20 000 000
# containers	100
# downloads	5 000 000
GBs	10 000 000
Energy used	590 000
Emissions kg CO2e	283 790
Short flights	1 612

Content of a container

```
➜  ~ docker run -it postgres /bin/sh
# cat /etc/passwd
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin
bin:x:2:2:bin:/bin:/usr/sbin/nologin
sys:x:3:3:sys:/dev:/usr/sbin/nologin
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/usr/sbin/nologin
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin
lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin
mail:x:8:8:mail:/var/mail:/usr/sbin/nologin
news:x:9:9:news:/var/spool/news:/usr/sbin/nologin
uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin
proxy:x:13:13:proxy:/bin:/usr/sbin/nologin
www-data:x:33:33:www-data:/var/www:/usr/sbin/nologin
backup:x:34:34:backup:/var/backups:/usr/sbin/nologin
list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin
irc:x:39:39:ircd:/run/ircd:/usr/sbin/nologin
_apt:x:42:65534::/nonexistent:/usr/sbin/nologin
nobody:x:65534:65534:nobody:/nonexistent:/usr/sbin/nologin
postgres:x:999:999::/var/lib/postgresql:/bin/bash
# 
```

Content of a container

```
➜  ~ docker run -it openjdk /bin/sh
sh-4.4# cat /etc/passwd |grep 'lp\|games'
lp:x:4:7:lp:/var/spool/lpd:/sbin/nologin
games:x:12:100:games:/usr/games:/sbin/nologin
sh-4.4#
```

Content of a container

```
sh-4.4# ls /etc
GREP_COLORS         csh.login    gnupg       issue          localtime
X11                 default      group       issue.net      login.defs
aliases             dnf          gshadow     krb5.conf      motd
alternatives        environment  gss         krb5.conf.d    mtab
bash_completion.d   ethertypes   host.conf   ld.so.cache    networks
bashrc              exports      hostname    ld.so.conf     nsswitch.conf
chkconfig.d         filesystems  hosts       ld.so.conf.d   nsswitch.conf.bak
crypto-policies     fonts        init.d      libaudit.conf  openldap
csh.cshrc           gcrypt       inputrc     libssh         opt
sh-4.4# du -sh /etc
3.1M    /etc
sh-4.4#
```

Content of a container

```
→  ~ docker run -it postgres /bin/sh
# du -sh /var/cache/*
4.0K    /var/cache/adduser
12K     /var/cache/apt
1.8M    /var/cache/debconf
12K     /var/cache/ldconfig
8.0K    /var/cache/postgresql
#
```

```
→  ~ docker run -it postgres /bin/sh
# ls -lh /sbin/
total 8.8M
-rwxr-xr-x 1 root root   3.1K Mar 26  2023 addgnupghome
lrwxrwxrwx 1 root root      7 May 25  2023 addgroup -> adduser
-rwxr-xr-x 1 root root   1.1K Jul 28  2023 add-shell
-rwxr-xr-x 1 root root    48K May 25  2023 adduser
-rwxr-xr-x 1 root root   132K Mar 28 09:52 agetty
-rwxr-xr-x 1 root root   2.2K Mar 26  2023 applygnupgdefaults
-rwxr-xr-x 1 root root    67K Mar  5  2023 badblocks
-rwxr-xr-x 1 root root    67K Mar 28 09:52 blkdiscard
-rwxr-xr-x 1 root root   195K Mar 28 09:52 blkid
-rwxr-xr-x 1 root root   131K Mar 28 09:52 blkzone
-rwxr-xr-x 1 root root   131K Mar 28 09:52 blockdev
-rwxr-xr-x 1 root root    67K Mar 28 09:52 chcpu
-rwxr-xr-x 1 root root    71K Mar 23  2023 chgpasswd
-rwxr-xr-x 1 root root   131K Mar 28 09:52 chmem
-rwxr-xr-x 1 root root    71K Mar 23  2023 chpasswd
-rwxr-xr-x 1 root root    67K Sep 20  2022 chroot
lrwxrwxrwx 1 root root      4 Mar 23  2023 cpgr -> cppw
-rwxr-xr-x 1 root root    73K Mar 23  2023 cppw
-rwxr-xr-x 1 root root    67K Mar 28 09:52 ctrlaltdel
-rwxr-xr-x 1 root root   266K Mar  5  2023 debugfs
```

Challenge

Can we remove wasted bits in our micro-OS filesystems?

Javascript

Repository

github.com/debug-js/debug

Homepage

github.com/debug-js/debug#readme

Weekly Downloads

274,735,961

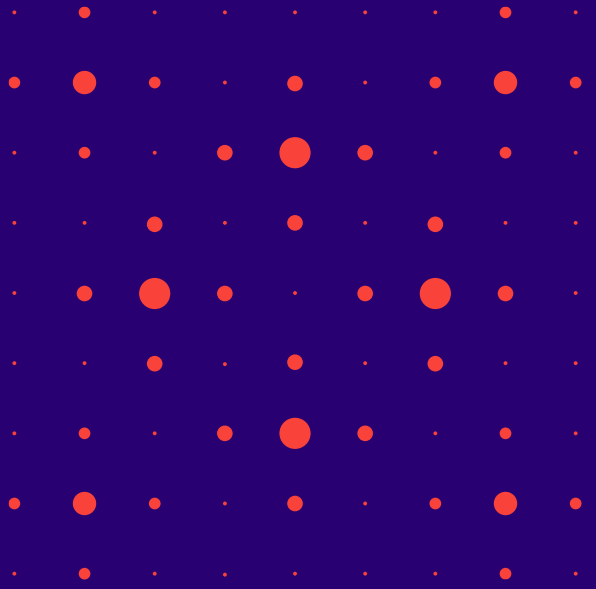
Debugs Readme	Pr week	Pr year
Network: kWh/GB	**0,059**	
Co2 factor g/kWh	**481**	
Bytes	22 000	
# containers	1	
# downloads	270 000 000	
GBs	5 940	
Energy used	350,46	18 223,92
Emissions saved kg CO2eq	169	8 766
Short flights	1	258

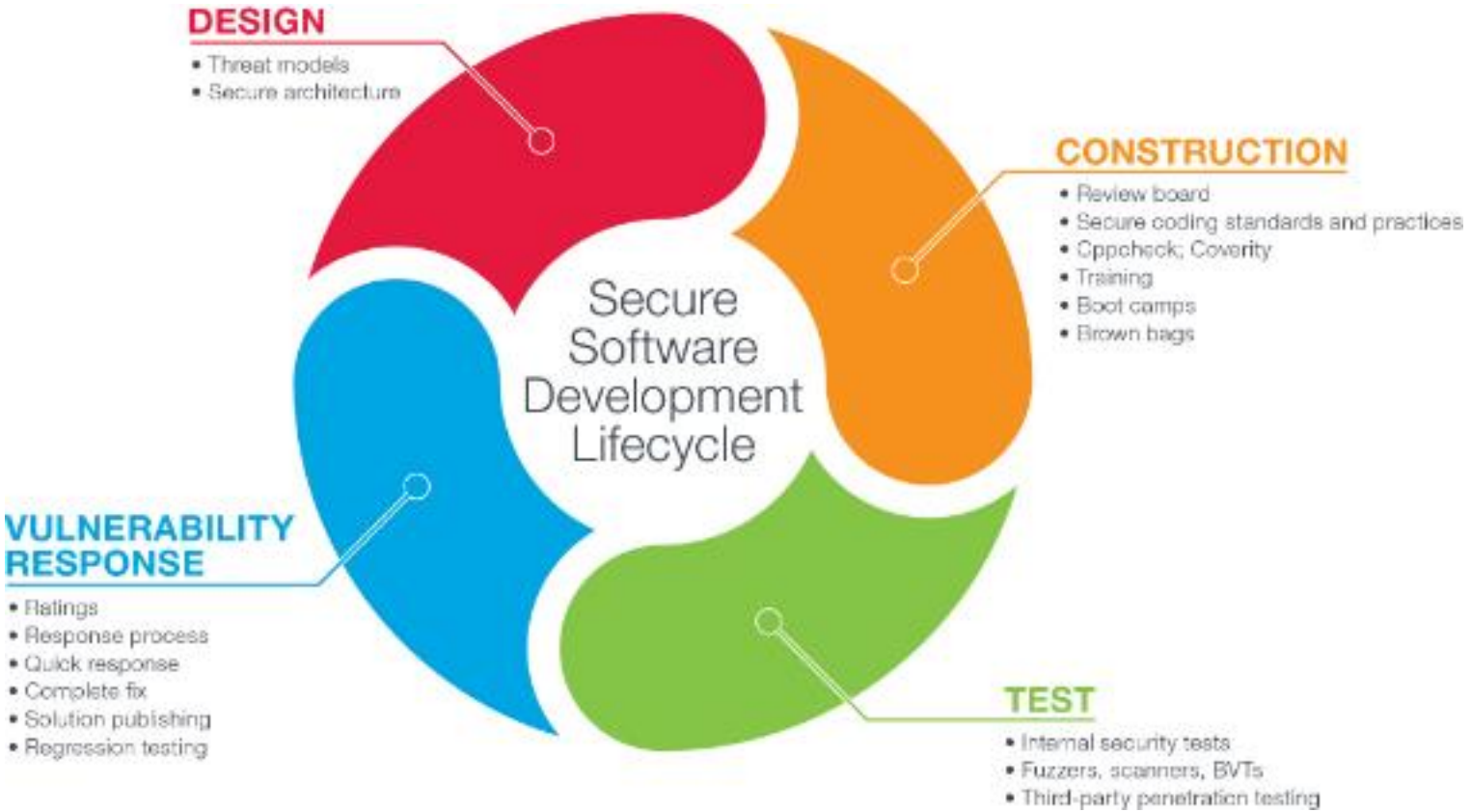
CI Build & Test

Total Estimated Carbon Cost of Testing Workflow for a Month

Repository	Estimated gCO2e consumed	Miles Driven by Car	Smartphones Charged to Full
curl	**6,824.27**	17.5	830
django	**337.78**	0.866	41.1
flask	**56.26**	0.144	6.8
openmw	**2,948.28**	7.6	359

What do we do about it?

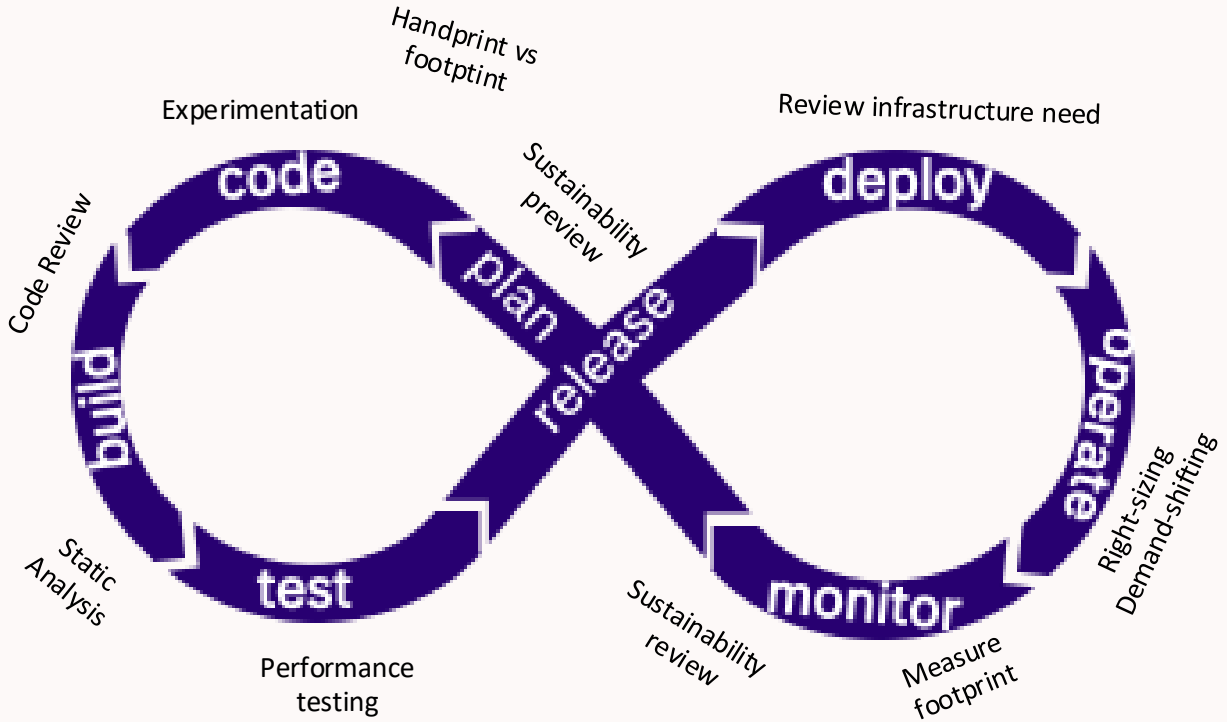




Source: https://www.netsecpros.com/secure-software-development-lifecycle/

A Green Coding SDLC

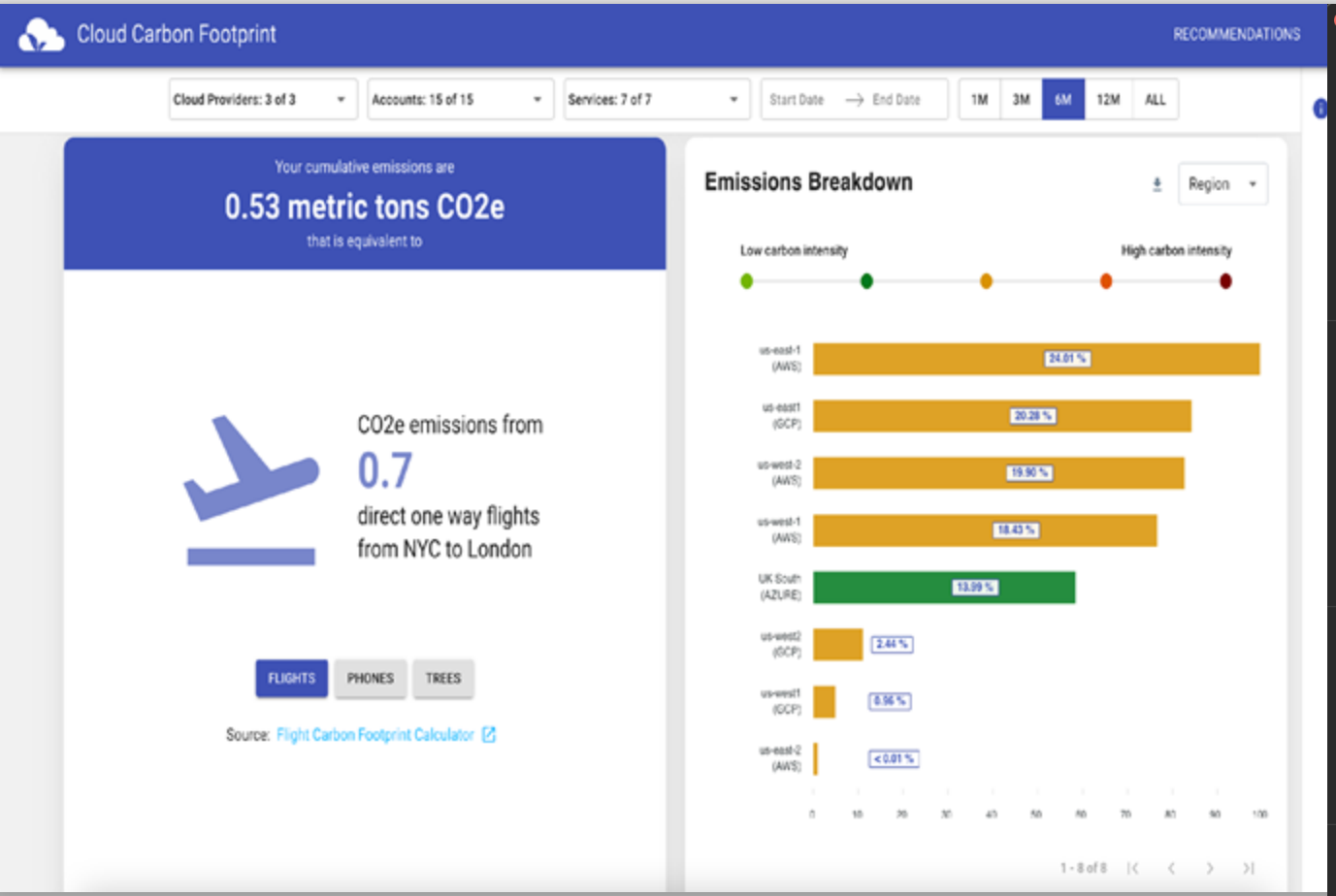
- Periodic Sustainability Review and Planning [6]
- Add activities to existing agile SDLC [7]

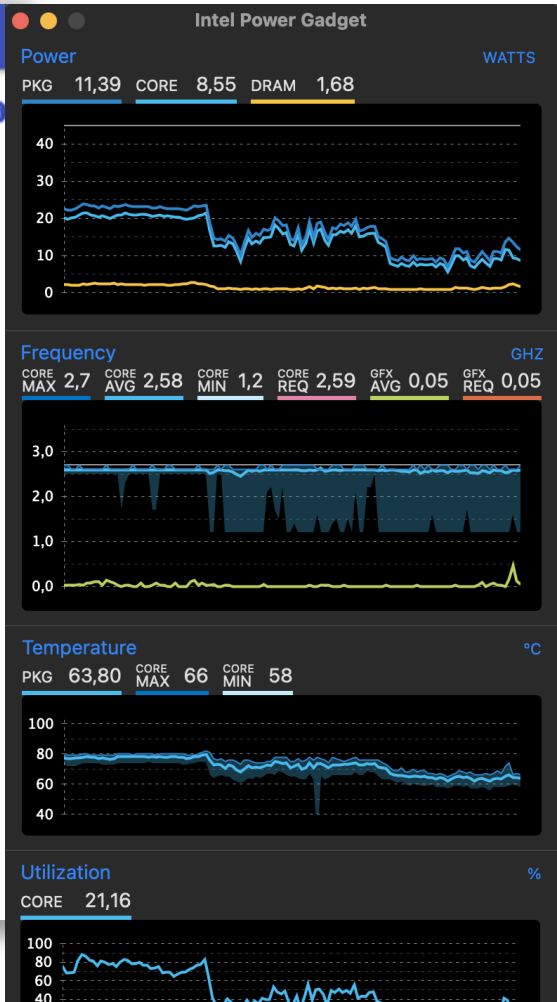


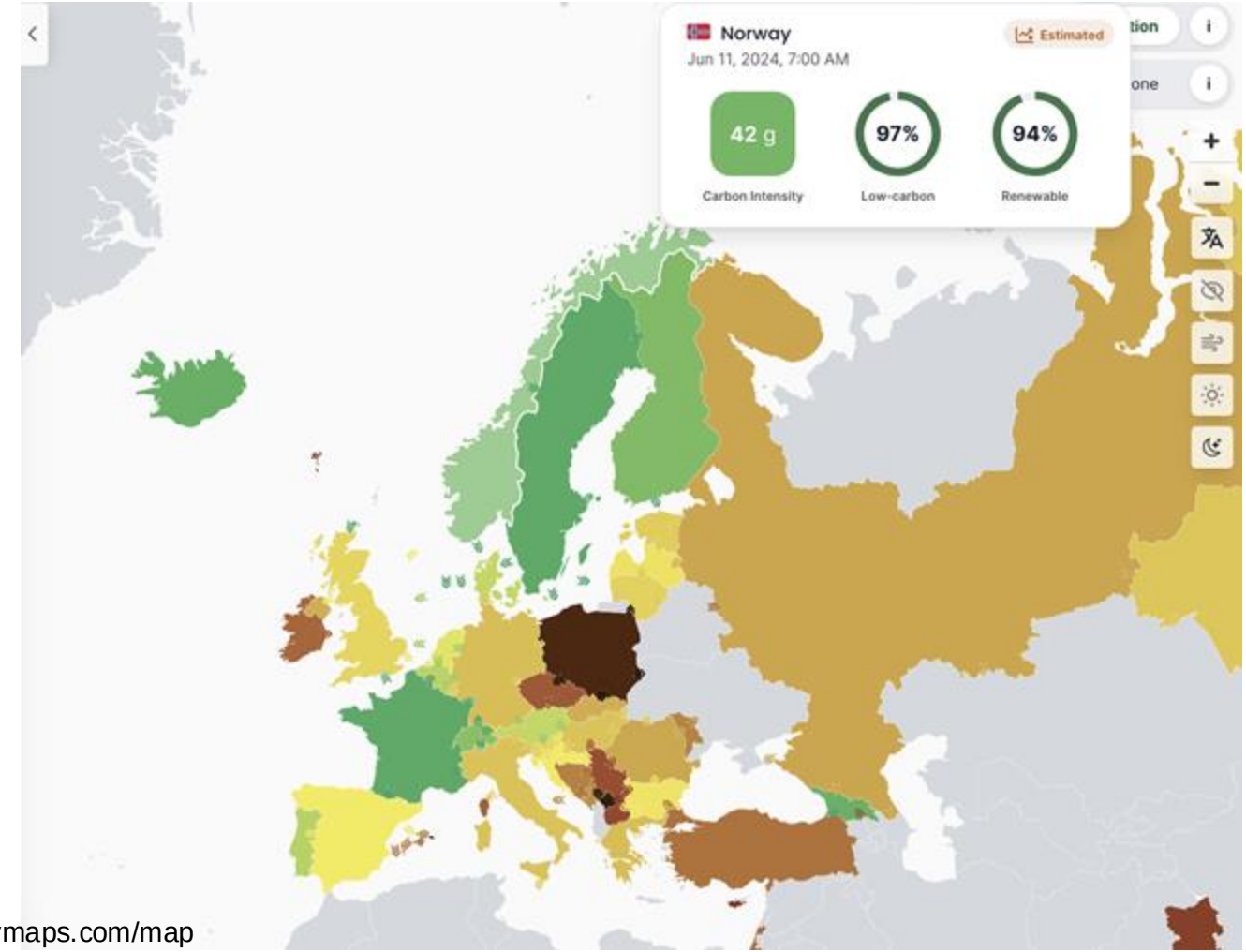
References:

[6] M. Dick, S. Naumann, Enhancing Software Engineering Processes towards Sustainable Software Product Design, EnviroInfo 2010

[7] Howard, Michael, and Steve Lipner. *The security development lifecycle*, 2006.


Cloud Carbon Footprint
RECOMMENDATIONS
Cloud Providers: 3 of 3
Accounts: 15 of 15
Services: 7 of 7
Start Date
End Date
1M
3M
6M
12M
ALL
Your cumulative emissions are
0.53 metric tons CO2e
that is equivalent to
CO2e emissions from
0.7
direct one way flights
from NYC to London
FLIGHTS
PHONES
TREES
Source: Flight Carbon Footprint Calculator
Emissions Breakdown
Region
Low carbon intensity
High carbon intensity
us-east-1 (AWS)
24.01 %
us-east1 (GCP)
20.28 %
us-west-2 (AWS)
19.90 %
us-west-1 (AWS)
18.43 %
UK South (AZURE)
13.99 %
us-west2 (GCP)
2.44 %
us-west1 (GCP)
0.96 %
us-east-2 (AWS)
< 0.01 %
1 - 8 of 8


Intel Power Gadget
Power
WATTS
PKG 11,39
CORE 8,55
DRAM 1,68
40
30
20
10
0
Frequency
GHZ
CORE MAX 2,7
CORE AVG 2,58
CORE MIN 1,2
CORE REQ 2,59
GFX AVG 0,05
GFX REQ 0,05
3,0
2,0
1,0
0,0
Temperature
°C
PKG 63,80
CORE MAX 66
CORE MIN 58
100
80
60
40
Utilization
%
CORE 21,16
100
80
60
40



Source:
https://app.electricitymaps.com/map

	Energy
(c) C	1.00
(c) Rust	1.03
(c) C++	1.34
(c) Ada	1.70
(v) Java	1.98
(c) Pascal	2.14
(c) Chapel	2.18
(v) Lisp	2.27
(c) Ocaml	2.40
(c) Fortran	2.52
(c) Swift	2.79
(c) Haskell	3.10
(v) C#	3.14
(c) Go	3.23
(i) Dart	3.83
(v) F#	4.13
(i) JavaScript	4.45
(v) Racket	7.91
(i) TypeScript	21.50
(i) Hack	24.02
(i) PHP	29.30
(v) Erlang	42.23
(i) Lua	45.98
(i) Jruby	46.54
(i) Ruby	69.91
(i) Python	75.88
(i) Perl	79.58

Source:
Energy efficiency across programming languages: how do energy, time, and memory relate? [6]

Have a question

Design an experiment

Run experiment

Publish results

```perl
my $start_time = time;

open(my $file, "<", "emails.txt") or die "Could not open file: $!";
my $content = do { local $/; <$file> };
close($file);

my $pattern = qr/[a-zA-Z0-9._%+-]+@[a-zA-Z0-9.-]+\.[a-zA-Z]{2,}/;
my @matches = $content =~ /$pattern/g;

my $end_time = time;
my $elapsed_time = $end_time - $start_time;

print "Found " . scalar(@matches) . " email addresses\n";
print "Elapsed time: $elapsed time seconds\n";
```

```csharp
public class RegexSpeedTest {
    0 references
    public static void Main(String[] args) {
        Stopwatch sw = new Stopwatch();
        sw.Start();
        String content = null;
        try {
            content = File.ReadAllText("../emails.txt");
        } catch (IOException e) {
            Console.WriteLine($"{e.Message}\n{e.StackTrace}");
        }

        String pattern = "[a-zA-Z0-9._%+-]+@[a-zA-Z0-9.-]+\\.[a-zA-Z]{2,}";
        MatchCollection matches = Regex.Matches(content, pattern);


        int numMatches = matches.Count();
        sw.Stop();


        Console.WriteLine("Found " + numMatches + " email addresses");
        Console.WriteLine("Elapsed time: " + sw.ElapsedMilliseconds / 1000.0 + " seconds");
    }
```

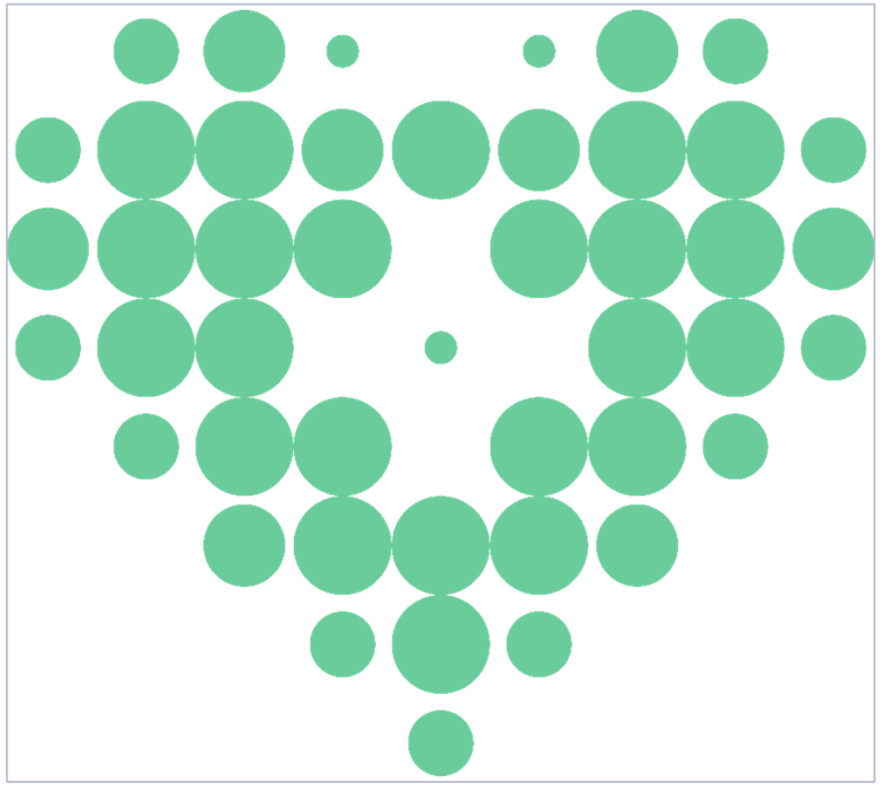
```
➜  dotnet git:(main) ✗ dotnet run
Found 609 email addresses
Elapsed time: 0,009 seconds
➜  dotnet git:(main) ✗
```

```
➜  Q5 Best language for regex git:(main) ✗ perl regex_speed_test.pl
Found 609 email addresses
Elapsed time: 0.00228095054626465 seconds
➜  Q5 Best language for regex git:(main) ✗
```

Know your footprint

Make reducing emissions a goal

Avoid obvious waste

Thank you!

- Any questions, comments are most welcome
  - Here and now!
  - Kent.Simonsen@tietoevry.com