Experimentação em Engenharia de Software

On the Performance of the Python Language

PG 54232
PG 55972
PG 57539

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Introduction

Python   Performance

Total							
	Energy			**Time**			**Mb**
(c) C	1.00		(c) C	1.00		(c) Pascal	1.00
(c) Rust	1.03		(c) Rust	1.04		(c) Go	1.05
(c) C++	1.34		(c) C++	1.56		(c) C	1.17
(c) Ada	1.70		(c) Ada	1.85		(c) Fortran	1.24
(v) Java	1.98		(v) Java	1.89		(c) C++	1.34
(c) Pascal	2.14		(c) Chapel	2.14		(c) Ada	1.47
(c) Chapel	2.18		(c) Go	2.83		(c) Rust	1.54
(v) Lisp	2.27		(c) Pascal	3.02		(v) Lisp	1.92
(c) Ocaml	2.40		(c) Ocaml	3.09		(c) Haskell	2.45
(c) Fortran	2.52		(v) C#	3.14		(i) PHP	2.57
(c) Swift	2.79		(v) Lisp	3.40		(c) Swift	2.71
(c) Haskell	3.10		(c) Haskell	3.55		(i) Python	2.80
(v) C#	3.14		(c) Swift	4.20		(c) Ocaml	2.82
(c) Go	3.23		(c) Fortran	4.20		(v) C#	2.85
(i) Dart	3.83		(v) F#	6.30		(i) Hack	3.34
(v) F#	4.13		(i) JavaScript	6.52		(v) Racket	3.52
(i) JavaScript	4.45		(i) Dart	6.67		(i) Ruby	3.97
(v) Racket	7.91		(v) Racket	11.27		(c) Chapel	4.00
(i) TypeScript	21.50		(i) Hack	26.99		(v) F#	4.25
(i) Hack	24.02		(i) PHP	27.64		(i) JavaScript	4.59
(i) PHP	29.30		(v) Erlang	36.71		(i) TypeScript	4.69
(v) Erlang	42.23		(i) Jruby	43.44		(v) Java	6.01
(i) Lua	45.98		(i) TypeScript	46.20		(i) Perl	6.62
(i) Jruby	46.54		(i) Ruby	59.34		(i) Lua	6.72
(i) Ruby	69.91		(i) Perl	65.79		(v) Erlang	7.20
(i) Python	75.88		(i) Python	71.90		(i) Dart	8.64
(i) Perl	79.58		(i) Lua	82.91		(i) Jruby	19.84

2
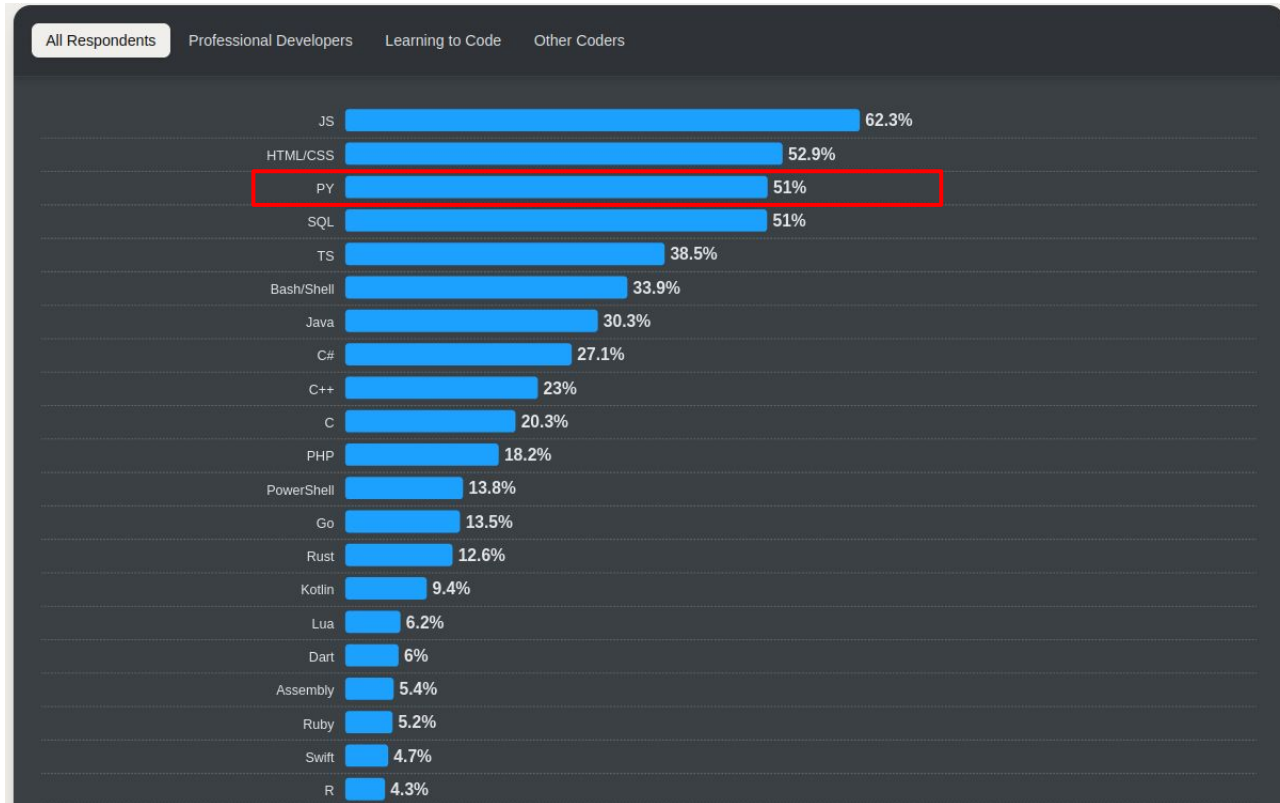
Python   Amongst

Python   Amongst

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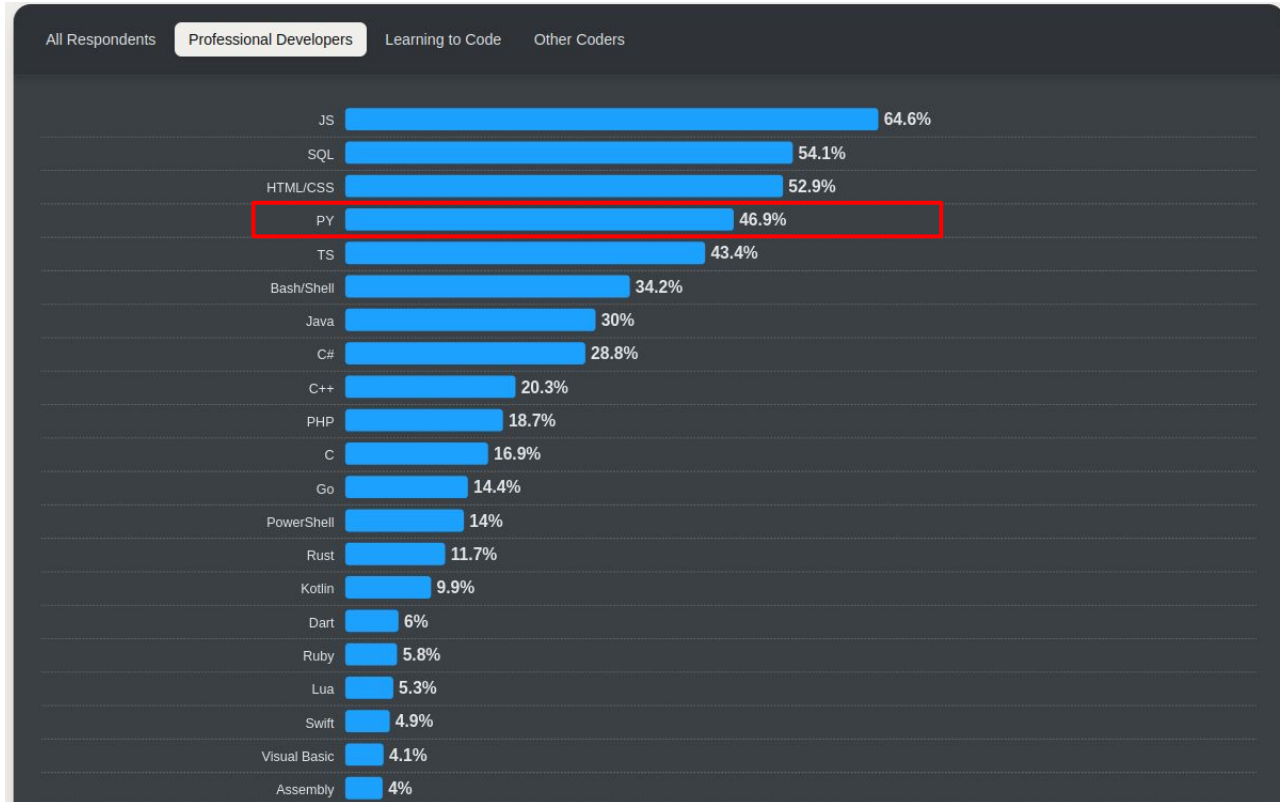
Python   Amongst
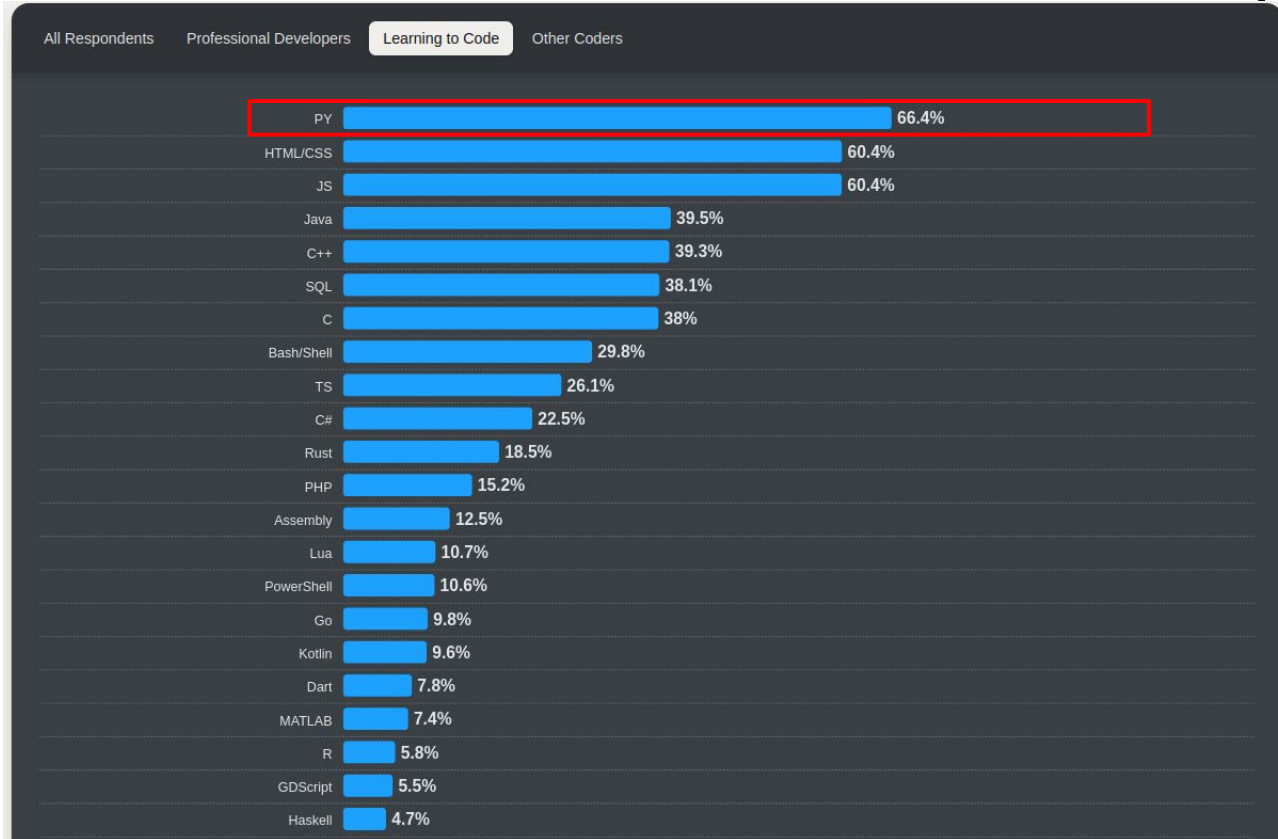
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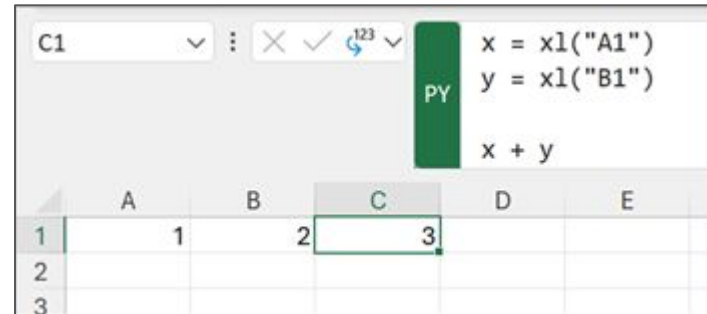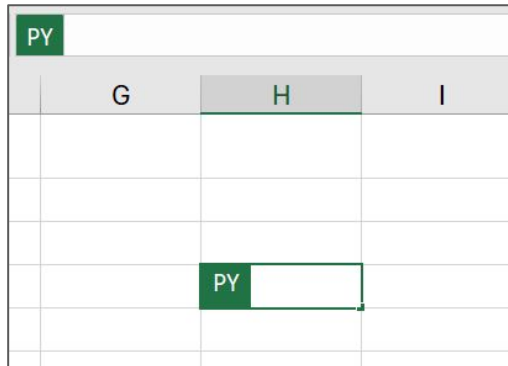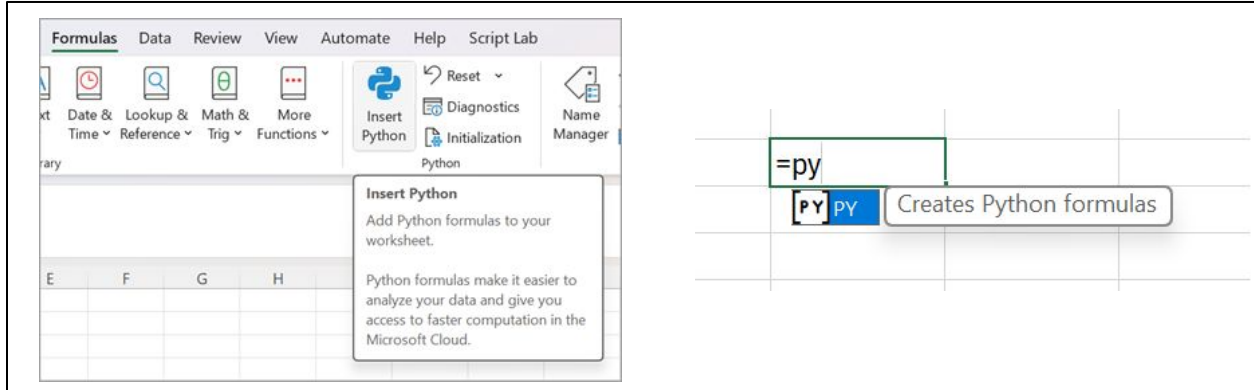
Python Pool

Python Pool

Chosen Criteria

https://devguide.python.org/versions/#versions
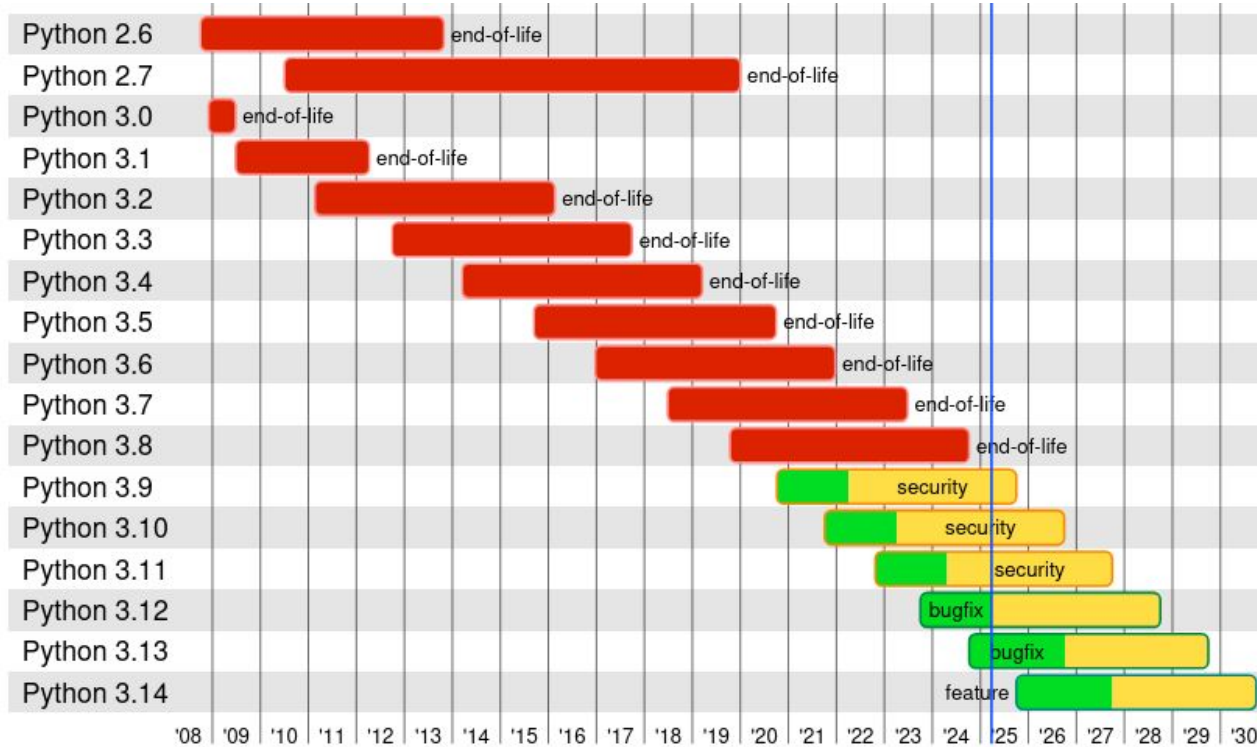
Python Pool

Interpreted Versions

Version	Release Date	Maintenance status
3.13.2	Feb. 4, 2025	Bugfix
3.13.1	Dec. 3, 2024	Bugfix
3.12.9	Feb. 4, 2025	Bugfix
3.12.8	Dec. 3, 2024	Bugfix
3.12.3	April 9, 2024	Bugfix
3.11.11	Dec. 3, 2024	Security
3.10.16	Dec. 3, 2024	Security
3.9.21	Dec. 3, 2024	Security
3.0.1	Feb. 13, 2009	End-of-life
2.7.18	April 20, 2020	End-of-life
2.0.1	June 22, 2001	End-of-life

https://www.python.org/downloads/

Python Pool

Python Compilers

Name	Version
Codon	0.18.2
Nuitka	0.4.1

Object of Research

Object of Research

- *RQ1*
  - Which interpreter best handles **recursion**?
- *RQ2*
  - Which interpreter best handles **iteration**?
- *RQ3*
  - Which interpreter handles **memory management** best?
- *RQ4*
  - Which interpreter handles **data querying and processing** best?
- *RQ5*
  - What's the most **green compiler**, and to which extent?

Methodology

Benchmark   RAPL

- Run 10x *via* RAPL
  - Delete min and max outlier
    - Mean
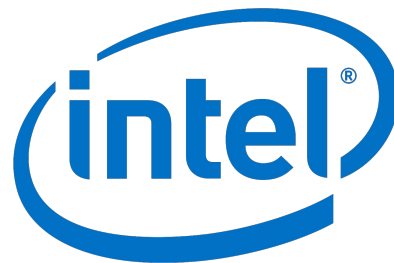
Environment

- CPU
  - Intel(R) Core(TM) i3-9100F CPU @ 3.60GHz
    - 4 Cores - 4 Threads

- RAM
  - DDR4 @ 2400 MHz
    - 8GB Dual Band (16 GB)

- ROM
  - M.2 2280 NVMe SSD
    - R 2,400 MB/s

- OS
  - Ubuntu 24.04.2 LTS
    - Linux 6.11.0-19-generic x86_64

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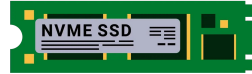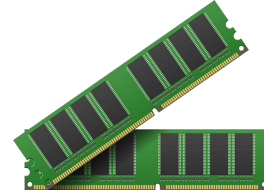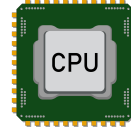
Environment

C Language Compiler

- GCC
  - V 13.3.0

Fibonacci

Fibonacci Recursive   Profile

- Time Complexity
  - O(N)

- *Object of Research*
  - Recursion

Fibonacci

Energy X Time

Fibonacci Recursive – Energy X Time

Fibonacci

Energy X Time

N	41		43	
Version	**Energy (J)**	**Time (s)**	**Energy (J)**	**Time (s)**
2.0.1	1 730	74	–	–
2.7.18	–	–	–	–
3.0.1	–	–	–	–
3.9.21	1 036	49	–	–
3.10.16	1 154	54	–	–
3.11.11	531	26	1 418	67
3.12.3	551	26	1 474	69
3.12.8	536	25	1 423	66
3.12.9	536	25	1 430	66
3.13.1	573	29	1 577	76
3.13.2	591	29	1 586	76

N	43	
Version	**Energy (J)**	**Time (s)**
Nuitka	975	46
Codon	64	0.003

20
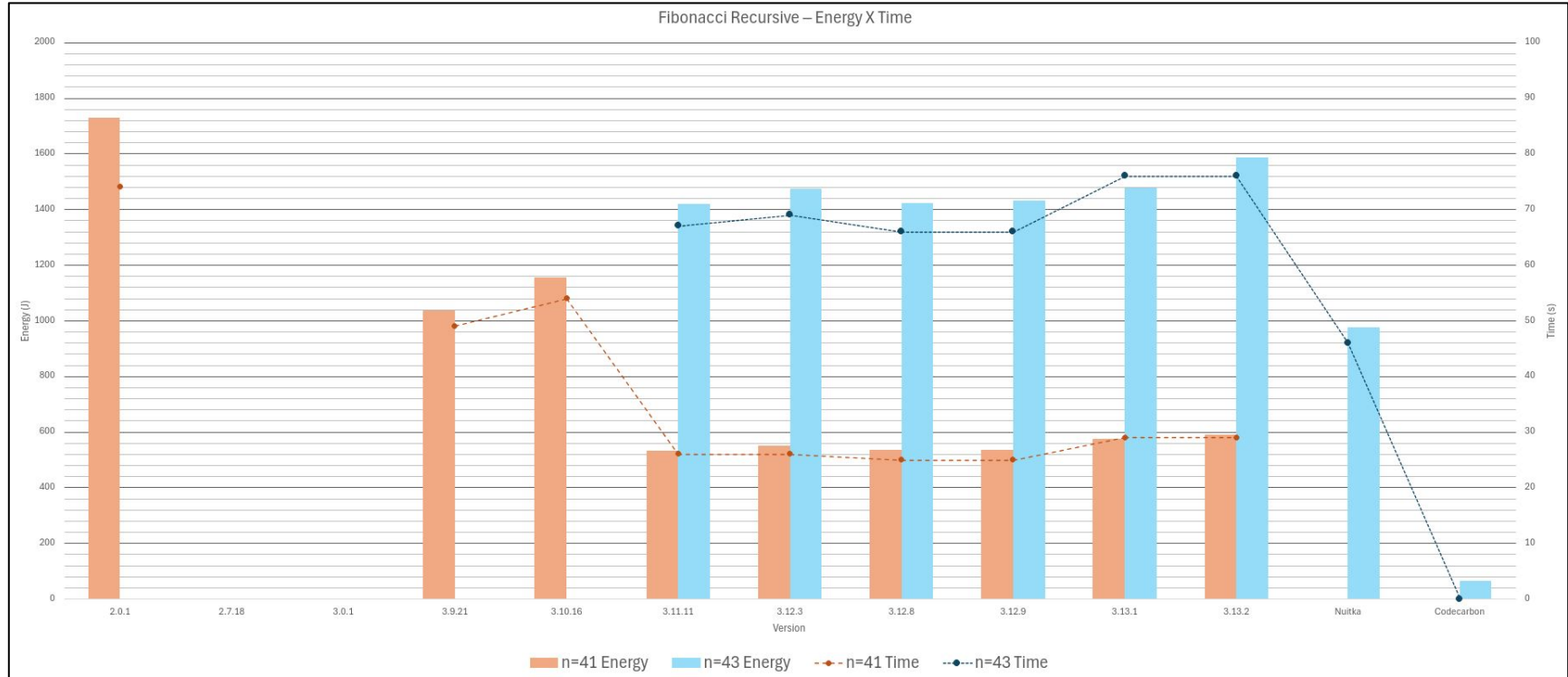
Fibonacci

N	41			43		
Version	**Power Up**	**Speed Up**	**Green Up**	**Power Up**	**Speed Up**	**Green Up**
2.0.1	1	1	1	–	–	–
2.7.18	–	–	–	–	–	–
3.0.1	–	–	---	–	–	–
3.9.21	0.91	1.53	1.67	–	–	–
3.10.16	0.92	1.38	1.50	–	–	–
3.11.11	0.89	2.91	3.26	1	1	1
3.12.3	0.90	2.82	3.14	1.01	0.97	0.96
3.12.8	0.91	2.94	3.22	1.02	1.02	1.00
3.12.9	0.91	2.93	3.22	1.02	1.01	0.99
3.13.1	0.84	2.55	3.02	0.98	0.88	0.90
3.13.2	0.86	2.52	2.92	0.98	0.88	0.89

N	43		
Version	**Power Up**	**Speed Up**	**Green Up**
3.11.11	1	1	1
Nuitka	1.00	1.46	1.45
Codon	0.97	21.30	22.01

Sieve of Eratosthenes

(Primes)

Sieve of Eratosthenes

Profile

- Time Complexity
  - O(N * log(log(N)))

- *Object of Research*
  - Iteration

Sieve of Eratosthenes
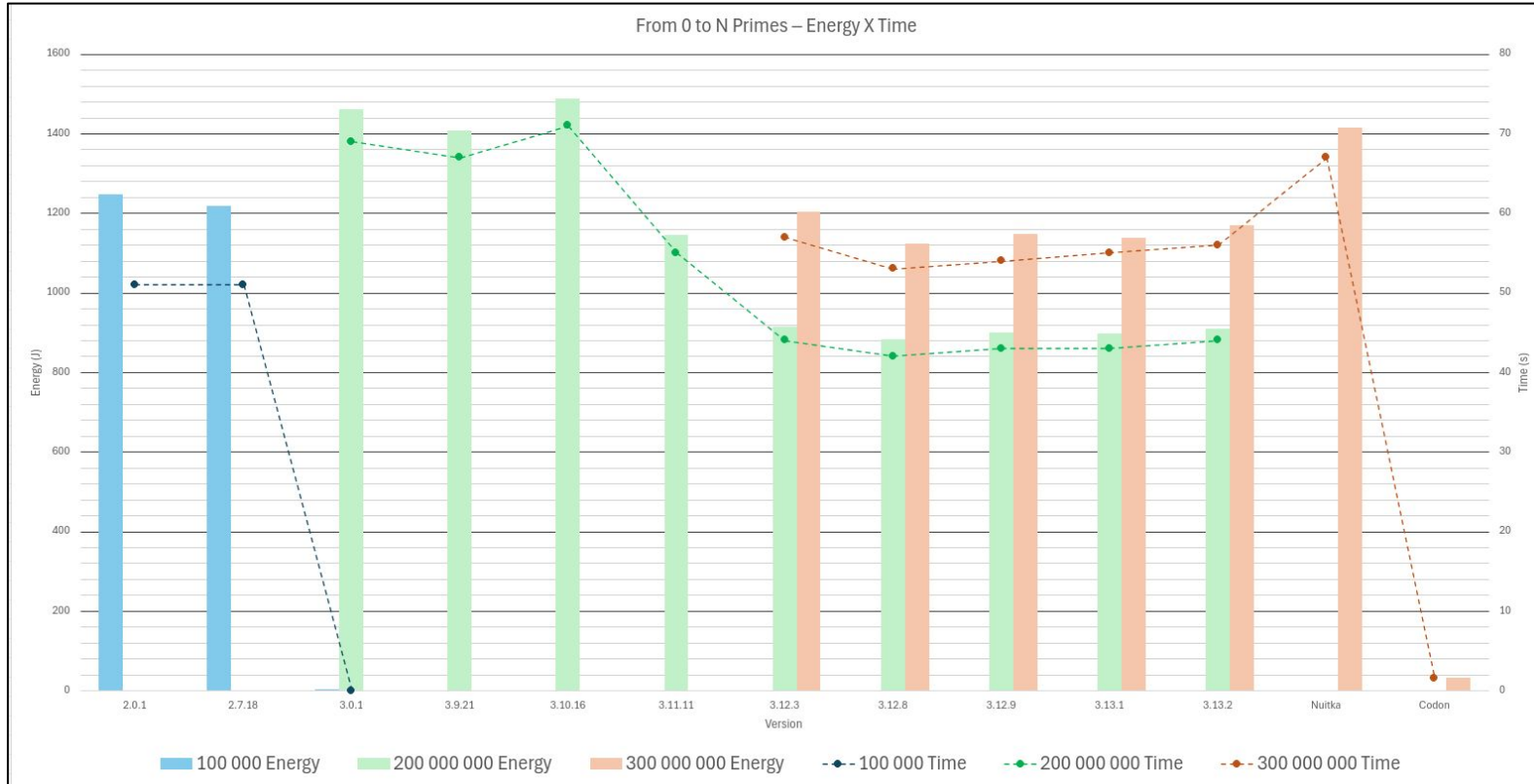
Energy X Time

Sieve of Eratosthenes

Energy X Time

From 0 to	100 000		200 000 000		300 000 000	
Version	Energy (J)	Time (s)	Energy (J)	Time (s)	Energy (J)	Time(s)
2.0.1	1 247	52	–	–	–	–
2.7.18	1 218	52	–	–	–	–
3.0.1	1	0	1 460	69	–	–
3.9.21	–	–	1 407	67	–	–
3.10.16	–	–	1 488	71	–	–
3.11.11	–	–	1 145	56	–	–
3.12.3	–	–	913	44	1 203	57
3.12.8	–	–	882	42	1 122	53
3.12.9	–	–	899	43	1 148	54
3.13.1	–	–	898	43	1 138	55
3.13.2	–	–	909	44	1 169	56

From 0 to	300 000 000	
Version	Energy (J)	Time (s)
Nuitka	1 415	67
Codon	33	2

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Primes

Power Up X Speed Up X Green Up

From 0 to	100 000			200 000 000			300 000 000		
Version	Power Up	Speed Up	Green Up	Power Up	Speed Up	Green Up	Power Up	Speed Up	Green Up
2.0.1	1	1	1	–	–	–	–	–	–
2.7.18	0.98	1.00	1.02	–	–	–	–	–	–
3.0.1	0.68	928.30	1 370.67	1	1	1	–	–	–
3.9.21	–	–	–	1.00	1.04	1.04	–	–	–
3.10.16	–	–	–	0.99	0.97	0.98	–	–	–
3.11.11	–	–	–	1.00	1.27	1.27	–	–	–
3.12.3	–	–	–	0.99	1.58	1.60	1	1	1
3.12.8	–	–	–	1.00	1.66	1.65	1.0	1.08	1.07
3.12.9	–	–	–	1.00	1.63	1.62	1.01	1.06	1.05
3.13.1	–	–	–	0.99	1.61	1.63	0.99	1.05	1.06
3.13.2	–	–	–	0.99	1.58	1.61	0.99	1.02	1.03

From 0 to	300 000 000		
Version	Power Up	Speed Up	Green Up
3.12.3	1	1	1
Nuitka	1.01	0.86	0.85
Codon	1.02	37.16	36.60

Bubble Sort

Bubble Sort

Profile

- Best case
  - O(N)

- Worst case
  - O(N²)

- Average case
  - O(N²)

- *Object of Research*
  - Memory management

Bubble Sort

Energy X Time

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Bubble Sort

Energy X Time

Integers	25 000		30 000	
Version	**Energy (J)**	**Time (s)**	**Energy (J)**	**Time (s)**
2.0.1	1 361	58	–	–
2.7.18	815	36	1 167	52
3.0.1	1 197	56	–	–
3.9.21	1 073	50	–	–
3.10.16	1 116	53	–	–
3.11.11	565	26	818	37
3.12.3	604	28	881	40
3.12.8	612	28	905	41
3.12.9	617	29	908	41
3.13.1	596	28	855	39
3.13.2	590	27	863	40

Integers	30 000	
Version	**Energy (J)**	**Time (s)**
Nuitka	1 073	49
Codon	57	3

30

Bubble Sort

Power Up X Speed Up X Green Up

Integers	25 000			30 000		
Version	Power Up	Speed Up	Green Up	Power Up	Speed Up	Green Up
2.0.1	1	1	1	–	–	–
2.7.18	0.96	1.60	1.67	1	1	1
3.0.1	0.90	1.03	1.14	–	–	–
3.9.21	0.90	1.15	1.27	–	–	–
3.10.16	0.89	1.09	1.22	–	–	–
3.11.11	0.93	2.24	2.41	0.98	1.39	1.43
3.12.3	0.92	2.07	2.25	0.97	1.28	1.32
3.12.8	0.92	2.04	2.22	0.97	1.25	1.29
3.12.9	0.92	2.03	2.20	0.97	1.25	1.29
3.13.1	0.92	2.10	2.28	0.96	1.32	1.36
3.13.2	0.91	2.11	2.31	0.96	1.30	1.35

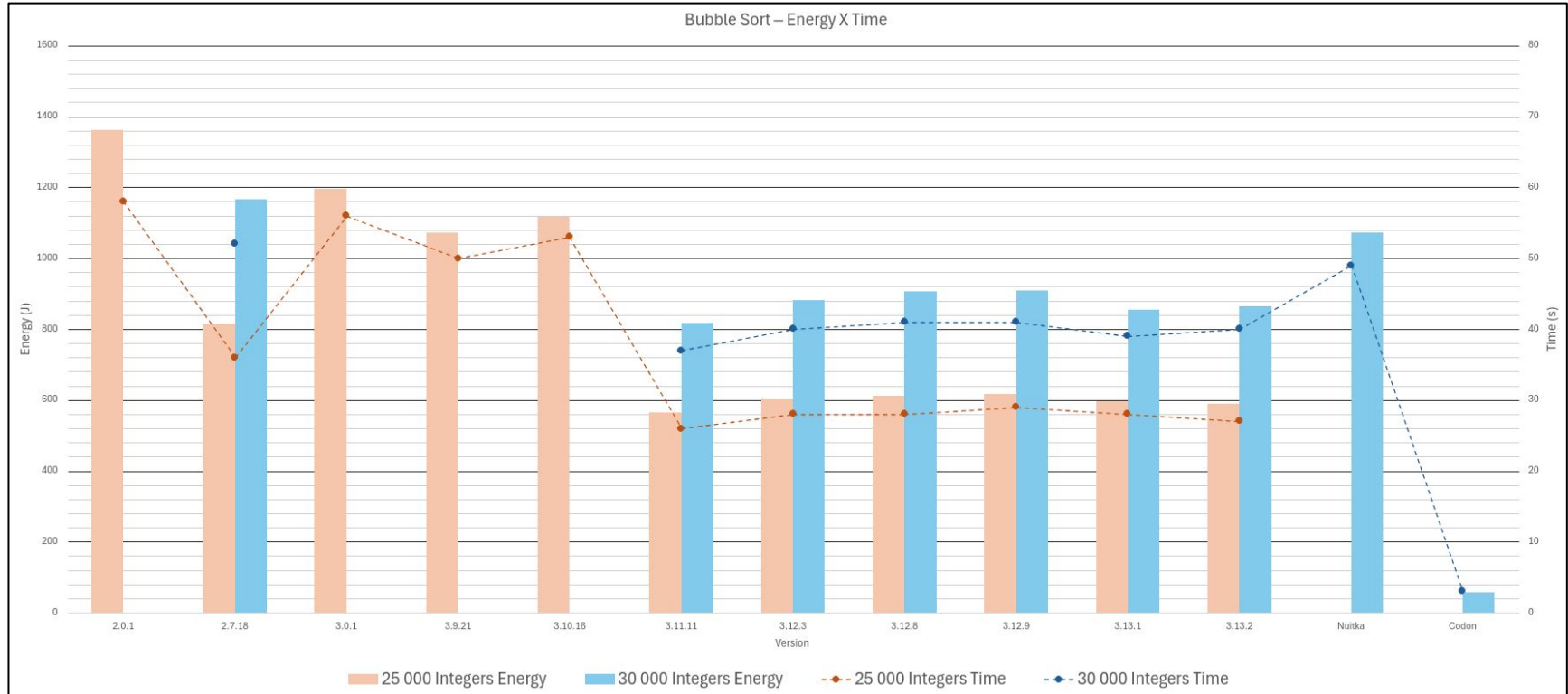| Integers	30 000		
Version	Power Up	Speed Up	Green Up
2.7.18	1	1	1
Nuitka	0.96	1.05	1.09
Codon	0.87	17.98	20.59

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Insertion Sort

Insertion Sort   Profile

- Best case
  - O(N)

- Worst case
  - O(N²)

- Average case
  - O(N²)

- *Object of Research*
  - Memory management

Insertion Sort

Energy X Time

Insertion Sort

Energy X Time
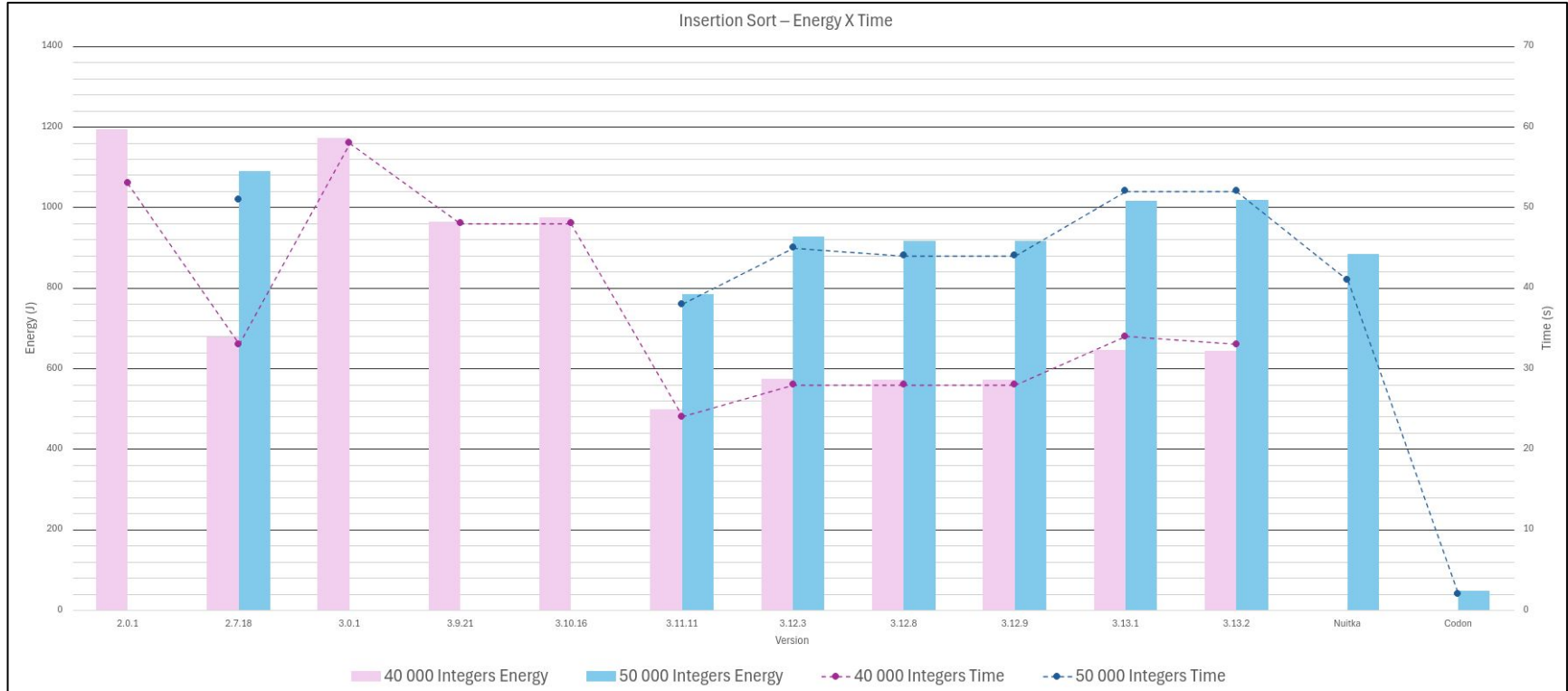
Integers	40 000		50 000	
Version	Energy (J)	Time (s)	Energy (J)	Time (s)
2.0.1	1 194	53	–	–
2.7.18	678	33	1 090	51
3.0.1	1 171	58	–	–
3.9.21	964	48	–	–
3.10.16	974	48	–	–
3.11.11	498	24	784	38
3.12.3	575	28	927	45
3.12.8	573	28	916	44
3.12.9	573	28	916	44
3.13.1	645	34	1 017	52
3.13.2	644	33	1 019	52

Integers	50 000	
Version	Energy (J)	Time (s)
Nuitka	883	41
Codon	47	2

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Insertion Sort

Power Up X Speed Up X Green Up

Integers	40 000			50 000		
Version	Power Up	Speed Up	Green Up	Power Up	Speed Up	Green Up
2.0.1	1	1	1	–	–	–
2.7.18	0.92	1.62	1.76	1	1	1
3.0.1	0.89	0.91	1.02	–	–	–
3.9.21	0.90	1.11	1.24	–	–	–
3.10.16	0.90	1.10	1.23	–	–	–
3.11.11	0.91	2.17	2.40	0.97	1.35	1.39
3.12.3	0.90	1.87	2.07	0.97	1.14	1.18
3.12.8	0.90	1.88	2.08	0.98	1.16	1.19
3.12.9	0.91	1.90	2.08	0.98	1.16	1.19
3.13.1	0.85	1.58	1.85	0.92	0.99	1.07
3.13.2	0.86	1.60	1.85	0.93	0.99	1.07

Integers	50 000		
Version	Power Up	Speed Up	Green Up
2.7.18	1	1	1
Nuitka	1.02	1.26	1.23
Codon	0.99	22.74	23.07

Shell Sort

Shell Sort   Profile

- Best case
  - O(N * log²(N))

- Worst case
  - O(2^N)

- Average case
  - O(N * log²(N))

- *Object of Research*
  - Memory management

Shell Sort

Energy X Time

Shell Sort – Energy X Time

Legend: 2 500 000 Integers Energy | 4 000 000 Integers Energy | 2 500 000 Integers Time | 4 000 000 Integers Time

Shell Sort

Energy X Time

Integers	2 500 000		4 000 000	
Version	Energy (J)	Time (s)	Energy (J)	Time (s)
2.0.1	1 434	63	–	–
2.7.18	806	40	–	–
3.0.1	1 268	62	–	–
3.9.21	1 082	53	–	–
3.10.16	1 113	55	–	–
3.11.11	582	28	1 110	55
3.12.3	636	32	1 228	61
3.12.8	646	32	1 240	62
3.12.9	645	32	1 248	62
3.13.1	652	32	1 233	62
3.13.2	646	32	1 245	62

Integers	4 000 000	
Version	Energy (J)	Time (s)
Nuitka	1 255	64
Codon	62	3

Shell Sort

Power Up X Speed Up X Green Up

Integers	2 500 000			4 000 000		
Version	Power Up	Speed Up	Green Up	Power Up	Speed Up	Green Up
2.0.1	1	1	1	–	–	–
2.7.18	0.90	1.60	1.78	–	–	–
3.0.1	0.90	1.02	1.13	–	–	–
3.9.21	0.91	1.20	1.33	–	–	–
3.10.16	0.90	1.15	1.29	–	–	–
3.11.11	0.92	2.26	2.46	1	1	1
3.12.3	0.89	2.01	2.25	0.98	0.89	0.90
3.12.8	0.89	1.97	2.22	1.00	0.89	0.89
3.12.9	0.89	1.97	2.22	0.99	0.88	0.89
3.13.1	0.89	1.95	2.20	0.98	0.88	0.90
3.13.2	0.88	1.96	2.22	0.98	0.88	0.89

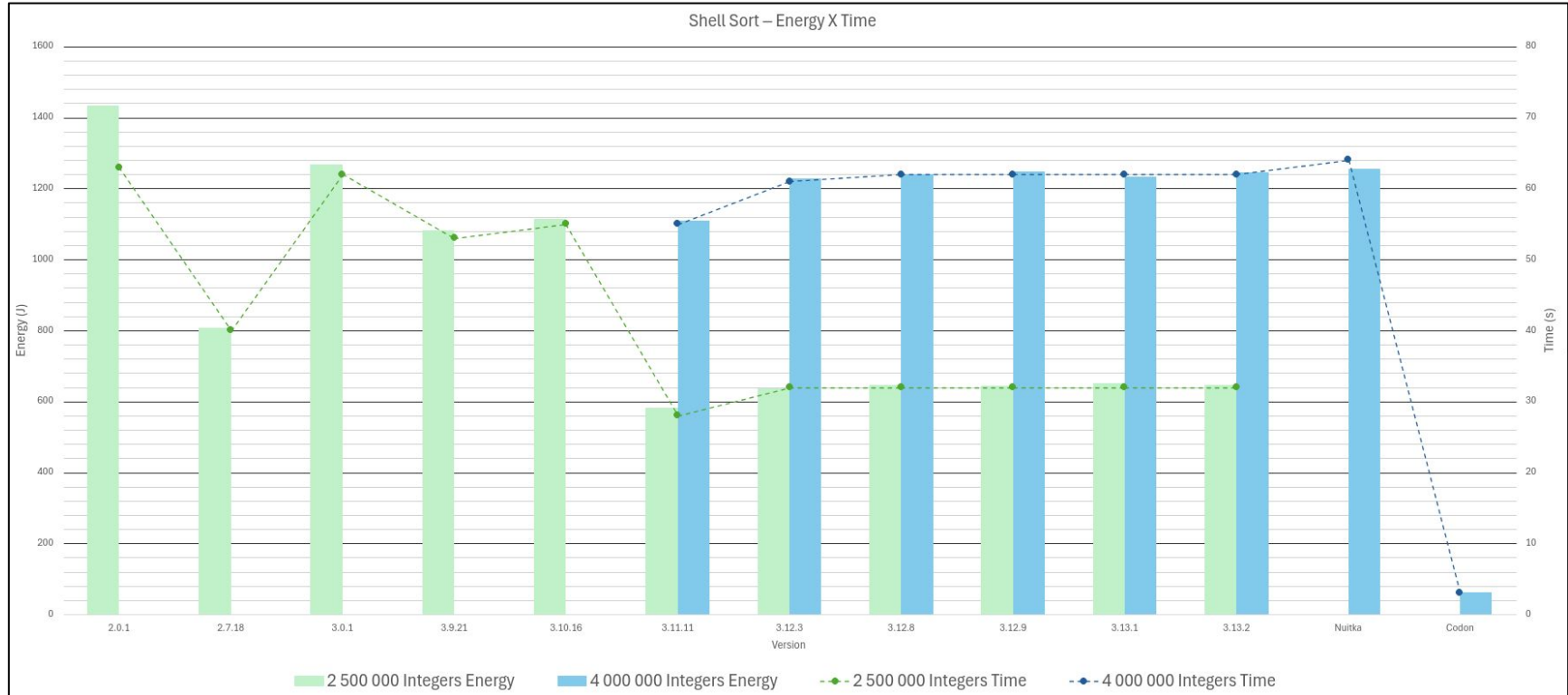| Integers	4 000 000		
Version	Power Up	Speed Up	Green Up
3.11.11	1	1	1
Nuitka	0.97	0.86	0.88
Codon	0.99	17.86	18.03

Merge Sort

Merge Sort

Profile

- Best case
  - O(N * log²(N))

- Worst case
  - O(N * log²(N))

- Average case
  - O(N * log²(N))

- *Object of Research*
  - Memory management
  - Context switching
  - *Recursion*

Merge Sort

Merge Sort – Energy X Time

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Merge Sort

Energy X Time
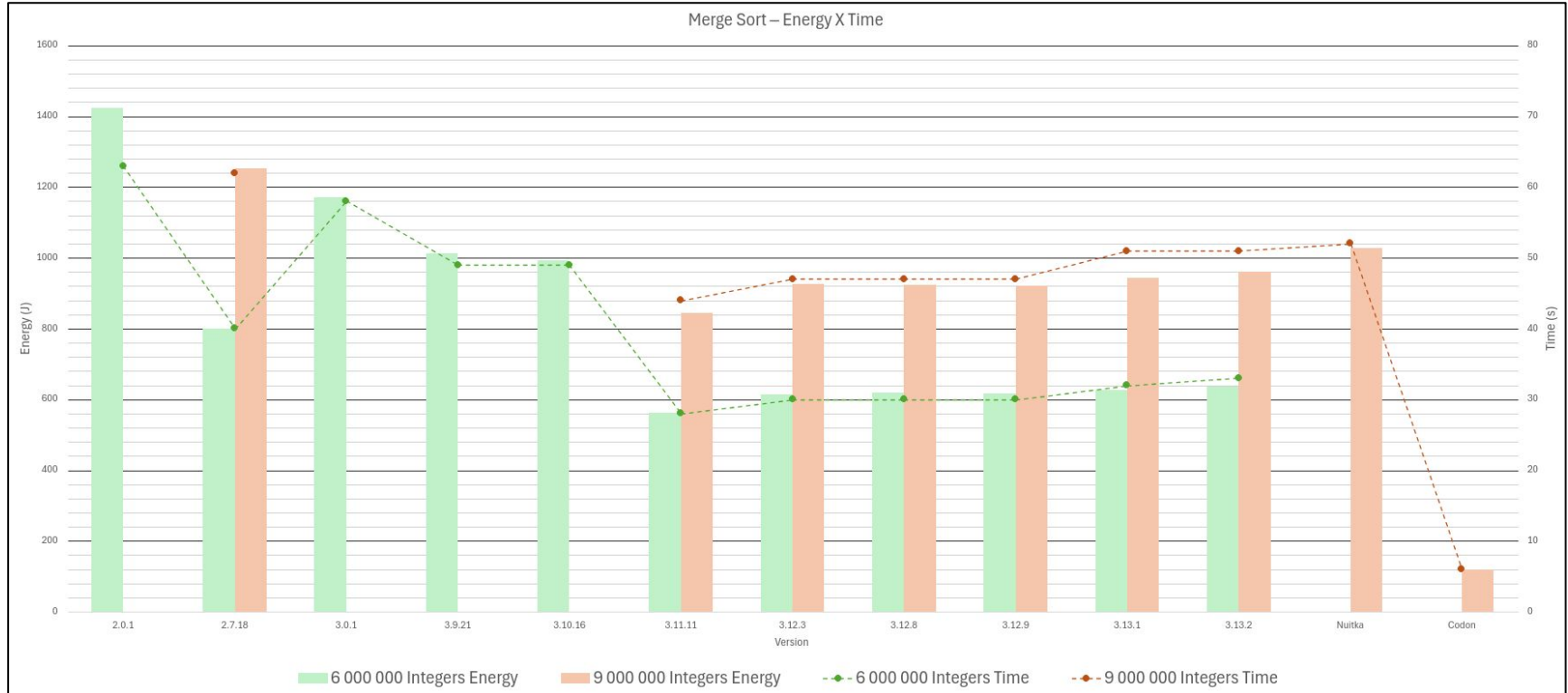
Integers	6 000 000		9 000 000	
Version	Energy (J)	Time (s)	Energy (J)	Time (s)
2.0.1	1 423	63	–	–
2.7.18	801	40	1 252	62
3.0.1	1 171	58	–	–
3.9.21	1 012	49	–	–
3.10.16	994	49	–	–
3.11.11	563	28	845	44
3.12.3	615	30	926	47
3.12.8	618	30	923	47
3.12.9	616	30	921	47
3.13.1	627	32	944	51
3.13.2	636	33	960	51

Integers	9 000 000	
Version	Energy (J)	Time (s)
Nuitka	1 028	52
Codon	118	6

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Merge Sort
Power Up X Speed Up X Green Up

Integers	6 000 000			9 000 000		
Version	Power Up	Speed Up	Green Up	Power Up	Speed Up	Green Up
2.0.1	1	1	1	–	–	–
2.7.18	0.90	1.60	1.78	1	1	1
3.0.1	0.90	1.09	1.22	–	–	–
3.9.21	0.91	1.29	1.41	–	–	–
3.10.16	0.91	1.30	1.43	–	–	–
3.11.11	0.89	2.26	2.53	0.95	1.40	1.48
3.12.3	0.90	2.09	2.31	0.96	1.30	1.35
3.12.8	0.91	2.09	2.30	0.96	1.30	1.36
3.12.9	0.92	2.12	2.31	0.97	1.32	1.36
3.13.1	0.87	1.97	2.27	0.92	1.22	1.33
3.13.2	0.87	1.94	2.24	0.92	1.20	1.30

Integers	9 000 000		
Version	Power Up	Speed Up	Green Up
2.7.18	1	1	1
Nuitka	0.97	1.18	1.22
Codon	1.06	11.20	10.60

Quick Sort

Quick Sort   Profile

- Best case
  - O(N * log²(N))

- Worst case
  - O(2^N)

- Average case
  - O(N * log²(N))

- *Object of Research*
  - Memory management

Quick Sort

Energy X Time

Quick Sort

Energy X Time
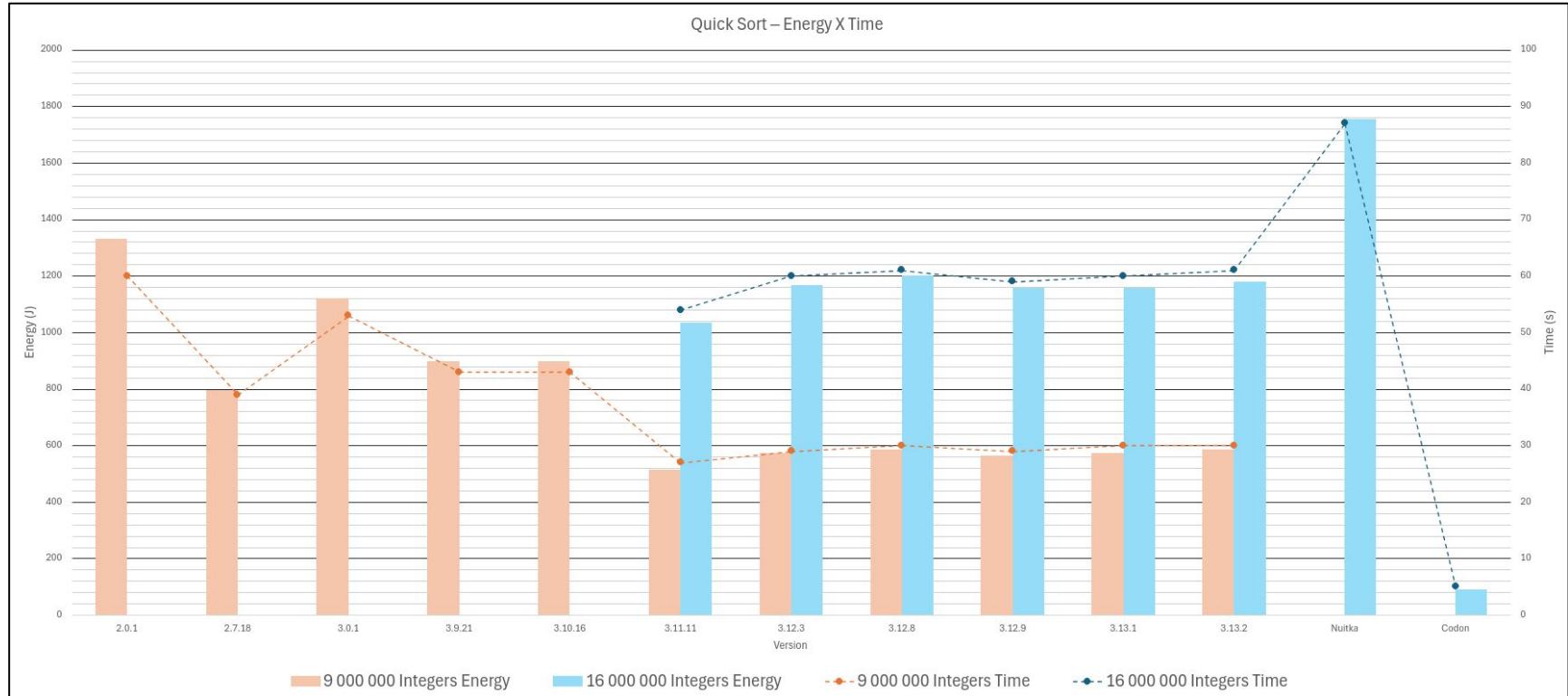
Integers	9 000 000		17 000 000	
Version	Energy (J)	Time (s)	Energy (J)	Time (s)
2.0.1	1 330	60	–	–
2.7.18	797	39	–	–
3.0.1	1 120	53	–	–
3.9.21	899	43	–	–
3.10.16	897	43	–	–
3.11.11	513	27	1 034	54
3.12.3	572	29	1 166	60
3.12.8	586	30	1 200	61
3.12.9	565	29	1 157	59
3.13.1	572	30	1 156	60
3.13.2	584	30	1 178	61

Integers	17 000 000	
Version	Energy (J)	Time (s)
Nuitka	1 755	87
Codon	91	5

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Quick Sort

Power Up X Speed Up X Green Up

Integers	9 000 000			17 000 000		
Version	Power Up	Speed Up	Green Up	Power Up	Speed Up	Green Up
2.0.1	1	1	1	–	–	–
2.7.18	0.92	1.54	1.67	–	–	–
3.0.1	0.95	1.12	1.19	–	–	–
3.9.21	0.93	1.38	1.48	–	–	–
3.10.16	0.93	1.38	1.48	–	–	–
3.11.11	0.85	2.21	2.59	1	1	1
3.12.3	0.87	2.02	2.32	1.03	0.91	0.89
3.12.8	0.88	2.00	2.27	1.04	0.90	0.86
3.12.9	0.86	2.03	2.35	1.02	0.92	0.89
3.13.1	0.86	2.00	2.32	1.01	0.91	0.89
3.13.2	0.87	1.99	2.28	1.02	0.90	0.88

Integers	17 000 000		
Version	Power Up	Speed Up	Green Up
3.11.11	1	1	1
Nuitka	1.06	0.62	0.59
Codon	1.01	11.45	11.33

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Tim Sort

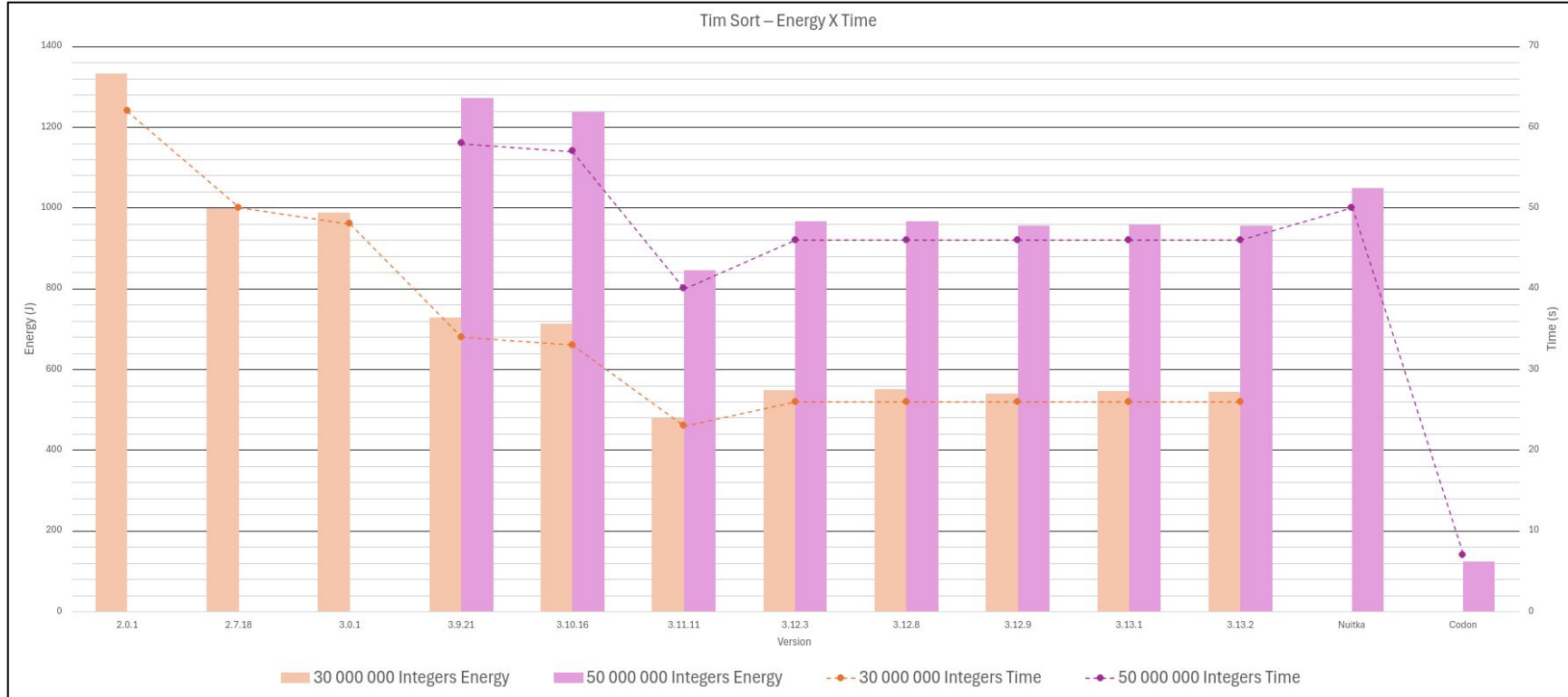# Tim Sort

- Best case
  - O(N)

- Worst case
  - O(N * log²(N))

- Average case
  - O(N * log²(N))

- *Object of Research*
  - Memory management
  - Context Switching
  - Recursion

Tim Sort

Energy X Time

Tim Sort

Energy X Time

Integers	30 000 000		50 000 000	
Version	Energy (J)	Time (s)	Energy (J)	Time (s)
2.0.1	1 333	62	–	–
2.7.18	999	50	–	–
3.0.1	987	48	–	–
3.9.21	727	34	1 271	58
3.10.16	712	33	1 238	57
3.11.11	478	23	844	40
3.12.3	549	26	966	46
3.12.8	550	26	967	46
3.12.9	540	26	955	46
3.13.1	547	26	957	46
3.13.2	544	26	955	46

Integers	50 000 000	
Version	Energy (J)	Time (s)
Nuitka	1 049	50
Codon	124	7

Tim Sort

Power Up X Speed Up X Green Up

Integers	30 000 000			50 000 000		
Version	Power Up	Speed Up	Green Up	Power Up	Speed Up	Green Up
2.0.1	1	1	1	–	–	–
2.7.18	0.92	1.23	1.33	–	–	–
3.0.1	0.95	1.28	1.35	–	–	–
3.9.21	1.01	1.84	1.83	1	1	1
3.10.16	1.00	1.87	1.87	0.99	1.02	1.03
3.11.11	0.97	2.69	2.79	0.96	1.44	1.51
3.12.3	0.97	2.35	2.43	0.96	1.26	1.32
3.12.8	0.97	2.35	2.42	0.96	1.27	1.31
3.12.9	0.97	2.39	2.47	0.96	1.28	1.33
3.13.1	0.97	2.36	2.44	0.95	1.27	1.33
3.13.2	0.96	2.36	2.45	0.95	1.27	1.33

Integers	50 000 000		
Version	Power Up	Speed Up	Green Up
3.9.21	1	1	1
Nuitka	0.97	1.18	1.21
Codon	0.84	8.63	10.25

Querying

Querying   Dataset

USER

Field	Type	Constraint
username	VARCHAR(75)	PK
name	VARCHAR(75)	–
gender	VARCHAR(1)	ENUM
birth_date	DATE	–
account_creation	DATE	–
pay_method	VARCHAR(16)	ENUM
account_status	VARCHAR(8)	ENUM

RIDE

Field	Type	Constraint
id	VARCHAR(75)	PK
date	DATE	–
driver	INTEGER	FK
user	VARCHAR(75)	FK
city	VARCHAR(64)	–
distance	INTEGER	–
score_user	FLOAT	–
score_driver	FLOAT	–
tip	FLOAT	–
comment	TEXT	–

DRIVER

Field	Type	Constraint
id	INTEGER	PK
name	VARCHAR(75)	–
gender	VARCHAR(1)	ENUM
birth_date	DATE	–
account_creation	DATE	–
account_status	VARCHAR(8)	ENUM
car_class	VARCHAR(8)	ENUM
license_plate	VARCHAR(8)	–
city	VARCHAR(64)	–

Querying

User Total Spent

Querying

User Total Spent

- Load
  - 1.38GB

- Validate + Structure
  - 107 900 026 words
    - avg. 12 length

  - Index Users by *username*
  - Index Drivers by *driver_id*
  - Group Rides by *username*

- Query
  - Access Rides by *username*
    - Access Drivers by *driver_id*
      - Get *car_class*
        - Calculate **fee**
    - Access Users by *username*
      - Get info
      - Get *birthday_date*
        - Calculate **age**

Querying

User Total Spent
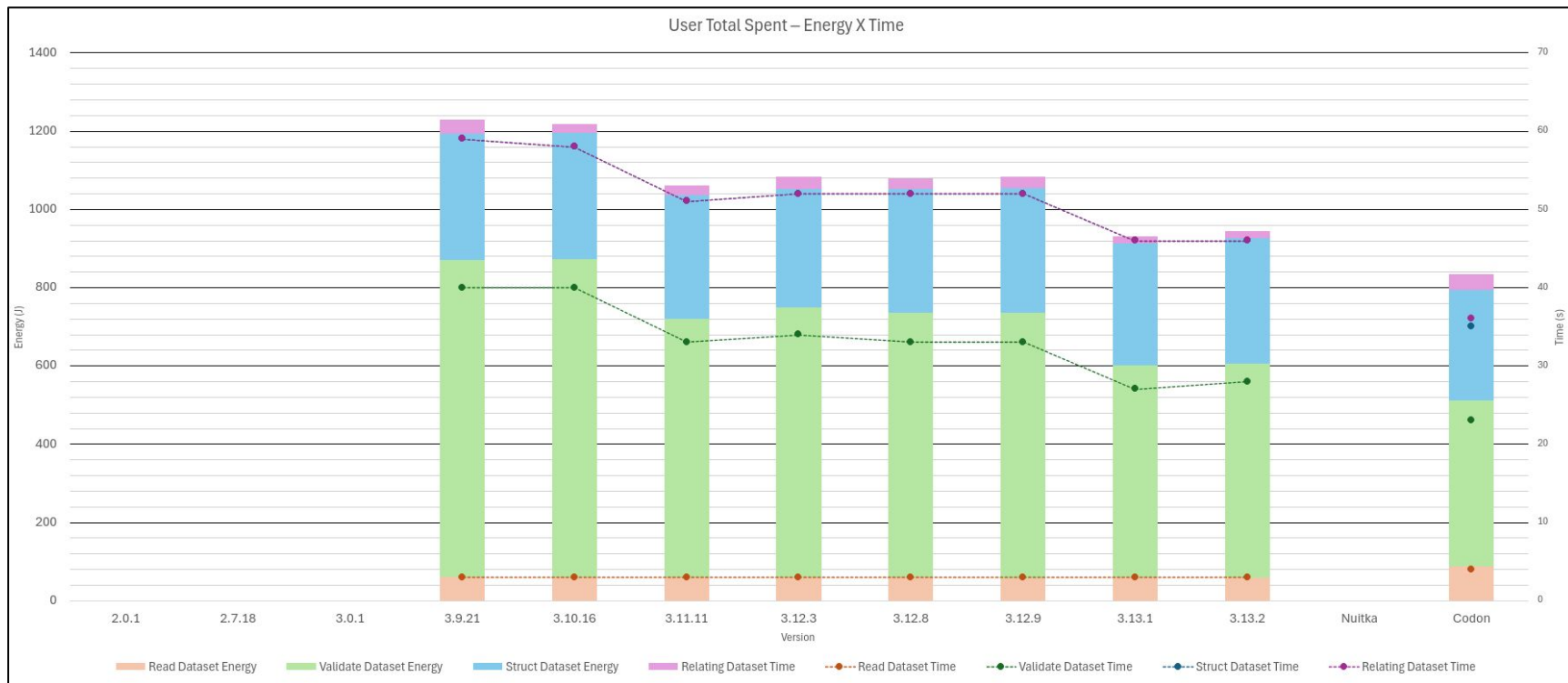
- Best case
  - $\Theta(\,1\,)$

- Worst case
  - $\Theta(\,N\,)$

- Average case
  - $\Theta(\,N\,)$

- *Object of Research*
  - Memory management
  - Context Switching
  - Parsing
  - Iteration

Querying – User Total Spent

Energy X Time

Querying – User Total Spent

Energy X Time

Table accesses	1		10		33	
Version	Energy (J)	Time (s)	Energy (J)	Time (s)	Energy (J)	Time(s)
2.0.1	–	–	–	–	–	–
2.7.18	–	–	–	–	–	–
3.0.1	–	–	–	–	–	–
3.9.21	1 229	59	1 196	60	1 224	59
3.10.16	1 219	59	1 203	59	1 225	59
3.11.11	1 061	52	1 041	52	1 066	52
3.12.3	1 084	53	1 063	53	1 084	53
3.12.8	1 080	52	1 050	53	1 081	53
3.12.9	1 083	53	1 061	53	1 086	53
3.13.1	931	46	918	46	932	46
3.13.2	945	46	926	46	942	46

Table accesses	1		10		33	
Version	Energy (J)	Time (s)	Energy (J)	Time (s)	Energy (J)	Time(s)
Nuitka	–	–	–	–	–	–
Codon	833	37	833	37	835	37

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Querying – User Total Spent

Power Up X Speed Up X Green Up

Accesses	33		
Version	Power Up	Speed Up	Green Up
2.0.1	–	–	–
2.7.18	–	–	–
3.0.1	–	–	–
3.9.21	1	1	1
3.10.16	1.01	1.01	1.00
3.11.11	1.00	1.15	1.15
3.12.3	1.00	1.13	1.13
3.12.8	1.00	1.13	1.13
3.12.9	1.00	1.13	1.13
3.13.1	0.98	1.29	1.31
3.13.2	0.99	1.28	1.30

Accesses	33		
Version	Power Up	Speed Up	Green Up
3.9.21	1	1	1
Nuitka	–	–	–
Codon	1.11	1.62	1.47

Querying

Drivers Top Score

Querying

Drivers Top Score

- Load
  - 1.38GB

- Validate
  - 107 900 026 words
    - avg. 12 length

- Structure
  - Index Drivers by *driver_id*
  - Group Rides by *driver_id*

- Query
  - Access Rides by *driver_id*
    - Group AVG(*score*) by *driver_id*
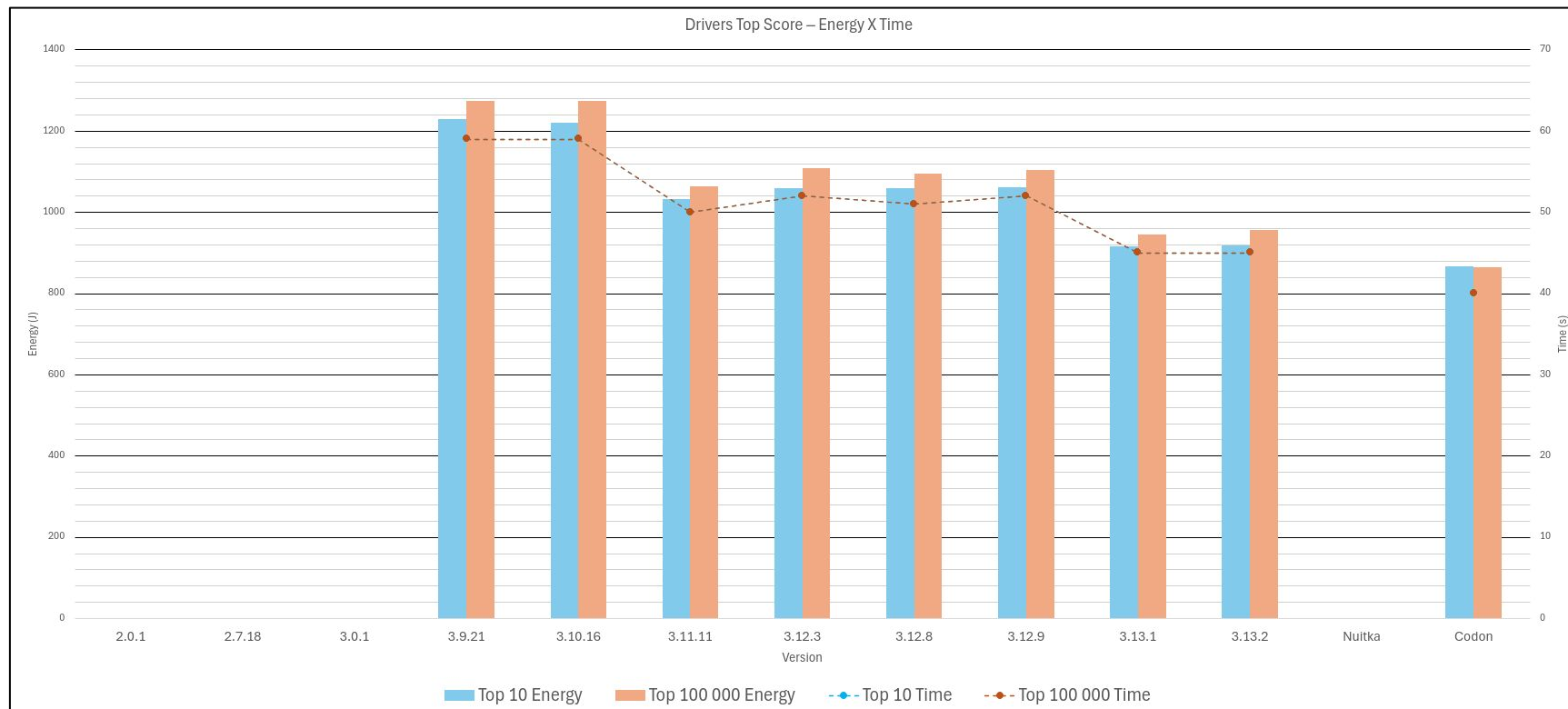 - Sort DESC
  - Slice

Querying

User Total Spent

- Best case
  - $\Theta(N)$

- Worst case
  - $\Theta(N)$

- Average case
  - $\Theta(N)$

- *Object of Research*
  - Memory management
  - Context Switching
  - Parsing
  - Iteration

Querying – Drivers Top Score

Energy X Time

Drivers Top Score – Energy X Time

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Querying – Drivers Top Score

Top	10		100 000	
Version	**Energy (J)**	**Time (s)**	**Energy (J)**	**Time (s)**
2.0.1	–	–	–	—
2.7.18	–	–	–	–
3.0.1	–	–	–	–
3.9.21	1 228	59	1 273	59
3.10.16	1 219	59	1 273	59
3.11.11	1 031	50	1 064	50
3.12.3	1 058	51	1 107	52
3.12.8	1 059	51	1 095	51
3.12.9	1 061	52	1 103	52
3.13.1	915	45	945	45
3.13.2	918	45	955	45

Energy X Time

Top	10		100 000	
Version	**Energy (J)**	**Time (s)**	**Energy (J)**	**Time (s)**
Nuitka	–	–	–	–
Codon	833	37	833	37

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Querying – Drivers Top Score

Power Up X Speed Up X Green Up

Top	100 000		
Version	Power Up	Speed Up	Green Up
2.0.1	–	–	–
2.7.18	–	–	–
3.0.1	–	–	–
3.9.21	1	1	1
3.10.16	1.00	1.00	1.00
3.11.11	0.99	1.18	1.20
3.12.3	1.00	1.14	1.15
3.12.8	0.99	1.15	1.16
3.12.9	1.00	1.15	1.15
3.13.1	0.98	1.32	1.35
3.13.2	0.98	1.30	1.33

Top	100 000		
Version	Power Up	Speed Up	Green Up
3.9.21	1	1	1
Nuitka	–	–	–
Codon	1.02	1.50	1.47

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Authors Notes

Threats to Validity

- ## Representativeness
    - CPU Architecture
    - Use Cases

- ## Energy consumption as a whole

Future Work

- Benchmark data structures

- Benchmark object oriented programming

- Context switching analysis

- Develop data analysis

Conclusion

- *RQ1:* Which interpreter best handles **recursion**?
  - Python 3.12.8
    - Fibonacci

- *RQ2:* Which interpreter best handles **iteration**?
  - Python 3.12.3
    - Sieve of Eratosthenes

- *RQ3:* Which interpreter handles **memory management** best?
  - Python 3.11.11
    - Sorting algorithms

- *RQ4:* Which interpreter handles **data querying and processing** best?
  - Python 3.13.1
    - Querying

- *RQ5:* What's the most **green compiler**, and to which extent?
  - Codon
    - More on the next slide…

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Conclusion

Overall

Version	Power Up	Speed Up	Green Up
Top Tiers	1	1	1
Codon	1.00	13.09	13.27

Recursion

Version	Power Up	Speed Up	Green Up
3.12.8	1	1	1
Codon	0.95	20.99	22.08

Data Manipulation

Version	Power Up	Speed Up	Green Up
3.13.1	1	1	1
Codon	1.10	1.20	1.09

Iteration

Version	Power Up	Speed Up	Green Up
3.12.8	1	1	1
Codon	1.09	34.51	34.14

Memory Management

Version	Power Up	Speed Up	Green Up
3.11.11	1	1	1
Codon	0.98	12.17	12.39

Experimentação em Engenharia de Software

On the Performance of the Python Language

PG 54232
PG 55972
PG 57539