Energy Efficiency Across Electronics Platform

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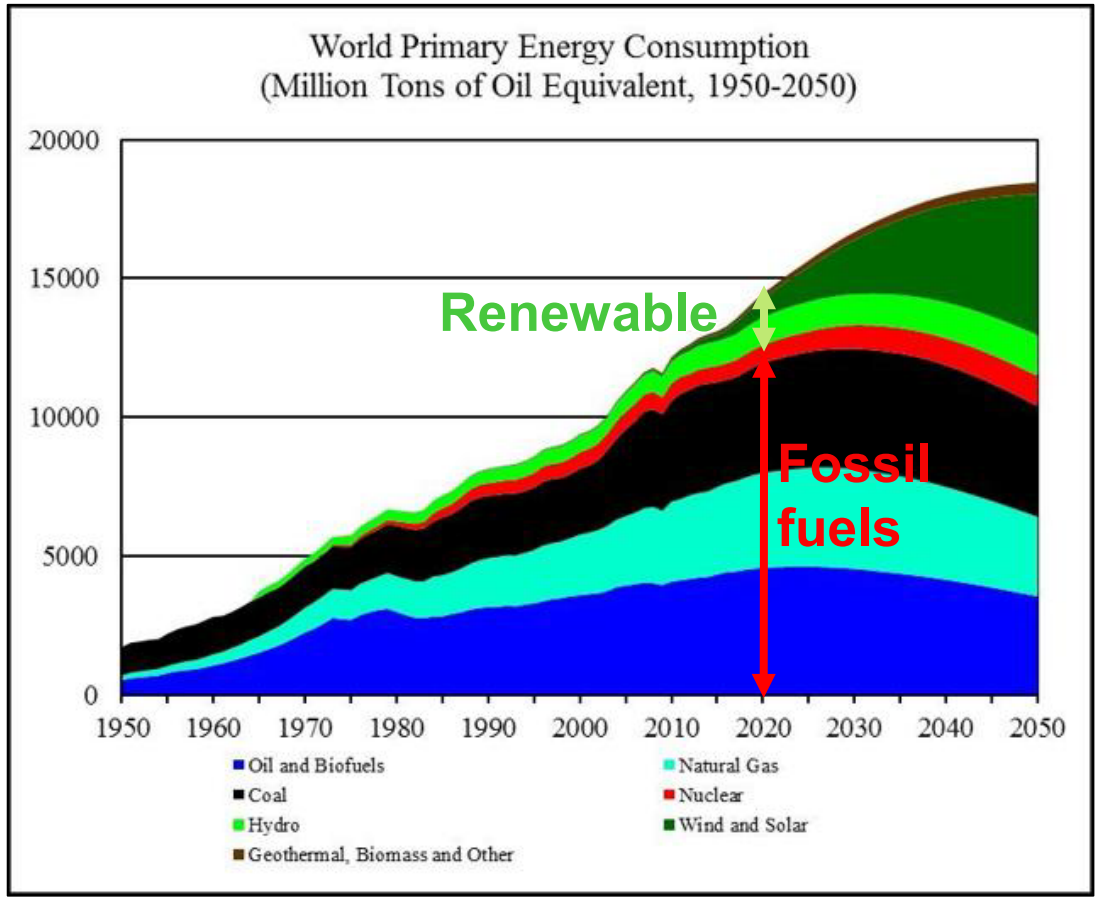
Global Energy Consumption Continues to Rise

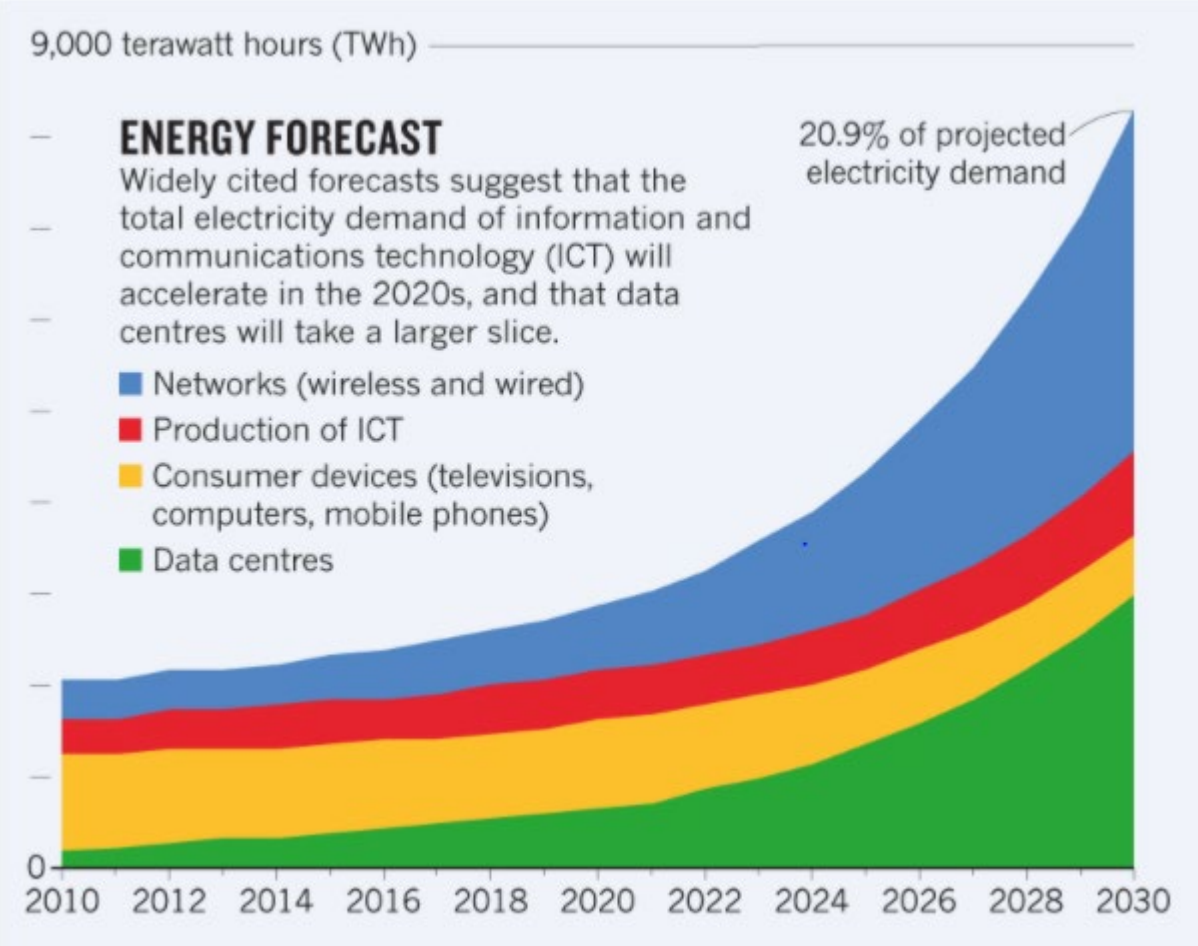


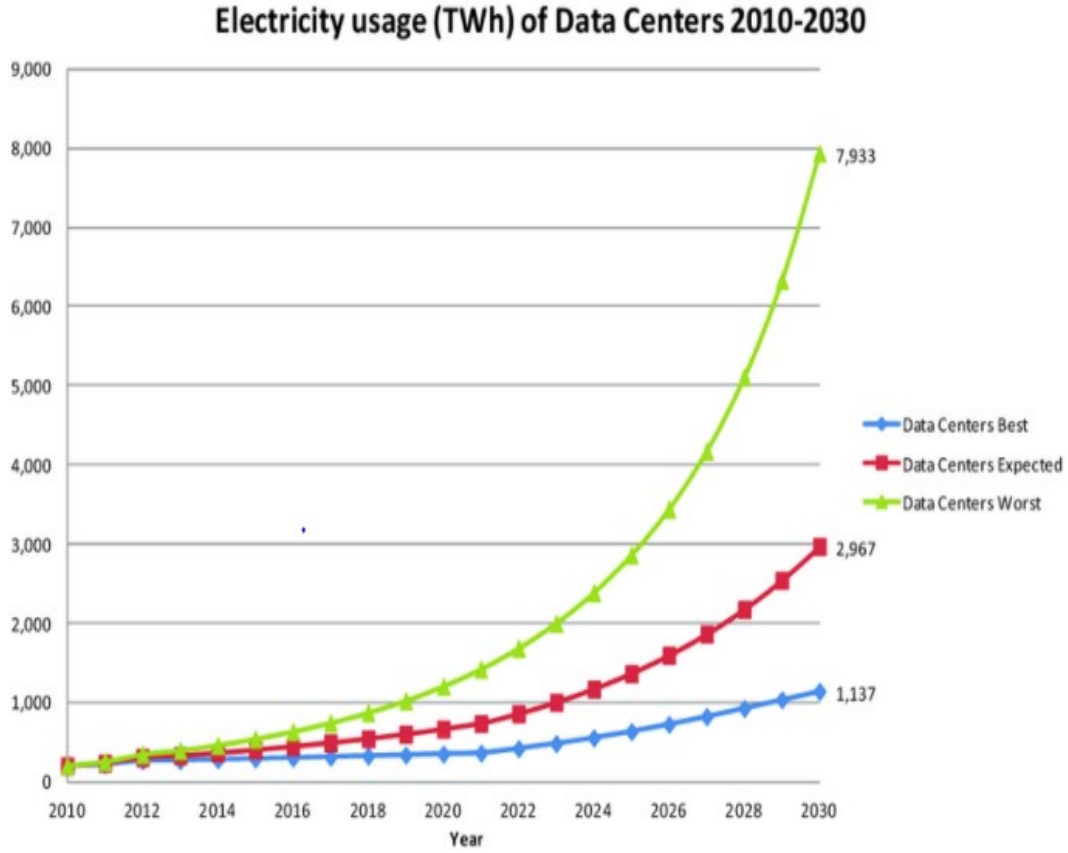
https://seekingalpha.com/article/4083393-world-energy-2017minus-2050-annual-report

7X increase in energy consumption since 1950 (70 yrs.)

80% energy from fossil fuels in 2020

Electronics Plays a Big Part in Energy Consumption





TWh = Trillion Watts
1 TWh → 200K homes continuously powered

Source: [How to stop data centres from gobbling up the world's electricity (nature.com)]

AI Chips vs. Human Brain – Much Scope for Power Reduction

Hardware	Year	Total Power
IBM Deep Blue	1997	**15 KW**
IBM Watson	2011	**200 KW**
Google AlphaGo	2016	**300 KW**
IBM Summit Super Computer	2018	**13 MW**

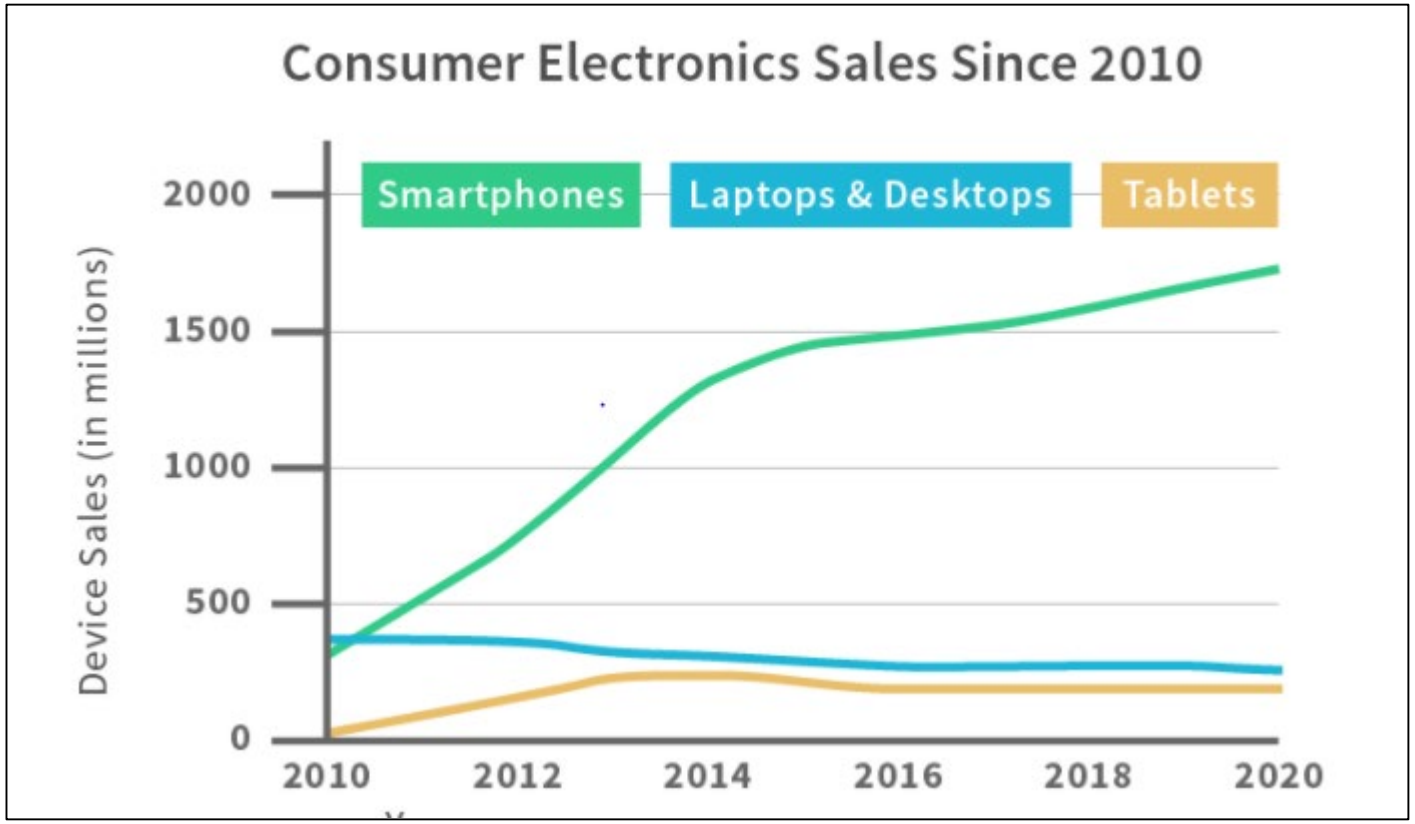
Human Brain

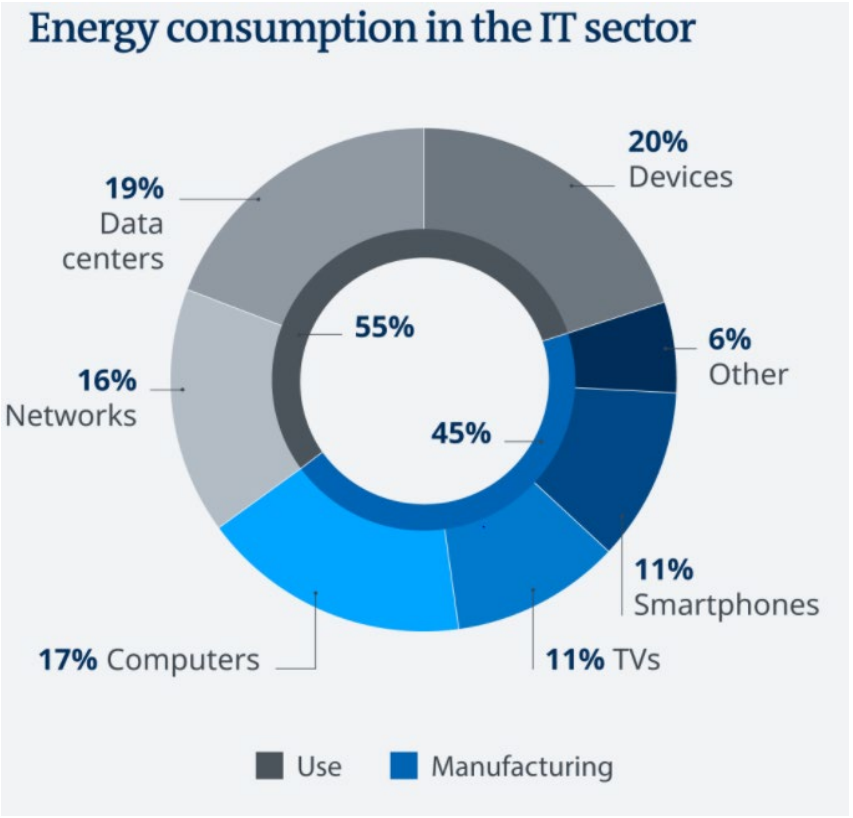
Average Power : 20W

Average Memory: 1.25 TB
Average Processing Power: 100 Teraflops
Average Frequency: 250-2,000 Hz

10K-100K times more power efficient!

Mobile Devices are Pervasive

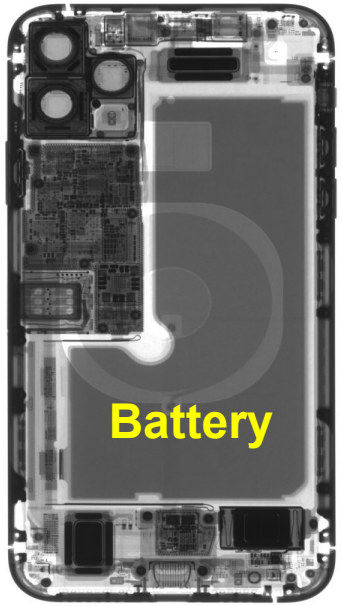




More than 1.5 Billion Smartphones sold annually

Energy Efficiency Key in Mobile Electronics and Mobile Computing

SmartPhoneX



SmartPhoneY

Battery dominated

+

More Apps

It is all about maximizing battery life – every nanowatt counts!!!

Global Impact on Energy Consumption from Mobile Devices

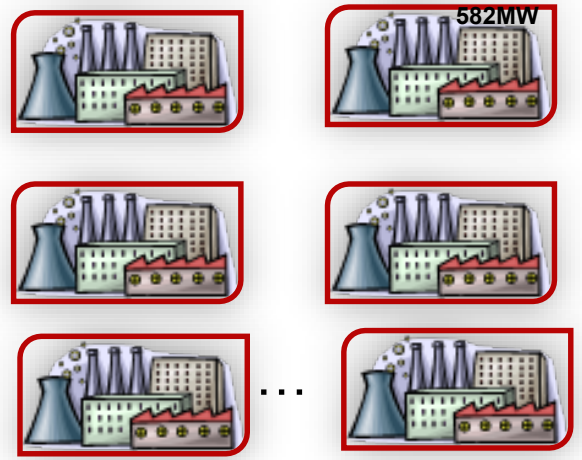
Power Efficiency Benchmark				
	Mfc. Process	FPS	Avg. Power (W)	Perf/W Efficiency
Phone1	7FFP	26.14	3.83	6.82 fps/W
Phone2	7FFP	34.00	6.21	5.47 fps/W
Phone3	7FF	19.32	3.81	5.07 fps/W
Phone4	7FF	26.59	5.56	4.78 fps/W
Phone5	7FF	16.17	4.69	3.44 fps/W
Phone6	8LPP	15.59	4.80	3.24 fps/W

1.5 Billion/yr

=

9315MW

=



19 Power Plants

(500MW)

The Impact of Energy Efficiency

4.5% reduction

Power Efficiency Benchmark

	Mfc. Process	FPS	Avg. Power (W)	Perf/W Efficiency
Phone1	7FFP	26.14	3.83	6.82 fps/W
Phone2	7FFP	34.00	6.21	5.47 fps/W
Phone3	7FF	19.32	3.81	5.07 fps/W
Phone4	7FF	26.59	5.56	4.78 fps/W
Phone5	7FF	16.17	4.69	3.44 fps/W
Phone6	8LPP	15.59	4.80	3.24 fps/W

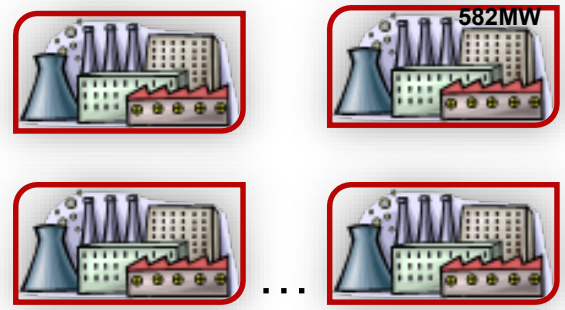
Energy Efficient Measures

Power Efficiency Benchmark

	Mfc. Process	FPS	Avg. Power (W)	Perf/W Efficiency
Phone1	7FFP	289.03	4.78	60.46 fps/W
Phone2	7FFP	328.90	5.93	55.46 fps/W
Phone3	7FF	197.80	3.95	50.07 fps/W
Phone4	7FF	271.86	6.10	44.56 fps/W
Phone5	7FF	167.16	4.10	40.70 fps/W
Phone6	10LPP	150.40	4.42	34.00 fps/W
	8LPP	166.00	4.96	33.40fps/W

.....

= 8895MW =



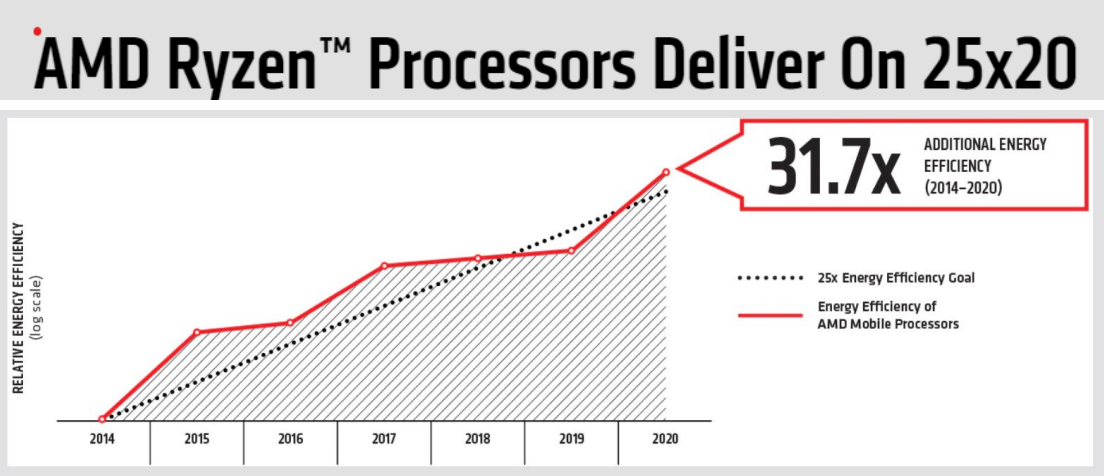
1.5 Billion/yr

18 Power Plants
i.e. 1 fewer!!!

https://www.amd.com/en/technologies/25x20

Example: AMD 25x20 Energy Efficiency Initiative

Goal: 25X reduction in energy efficiency by 2020



84% LESS

Energy consumption

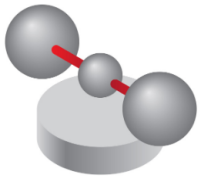
80% LESS

Average compute time for a given task

An enterprise that upgrades 50,000 AMD laptops from 2014 models to 2020 models would save

1.4 MILLION

Kilowatt hours



1 MILLION

Kilograms of carbon dioxide equivalent emissions

EQUAL TO 16,000

Tree seedlings grown for 10 years

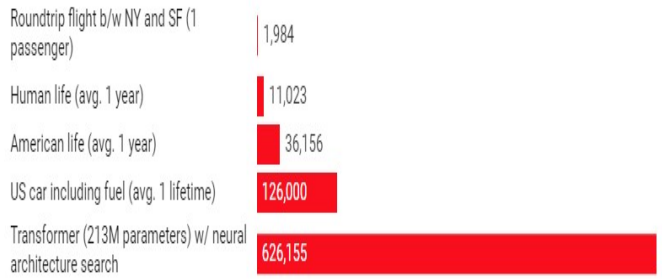
Artificial Intelligence/Machine Learning Energy Explosion

7 important benefits of AI for business

1. Efficiency and productivity gains
2. Improved speed of business
3. New capabilities and business model expansion
4. Better customer service
5. Improved monitoring
6. Better quality and reduction of human error
7. Better talent management

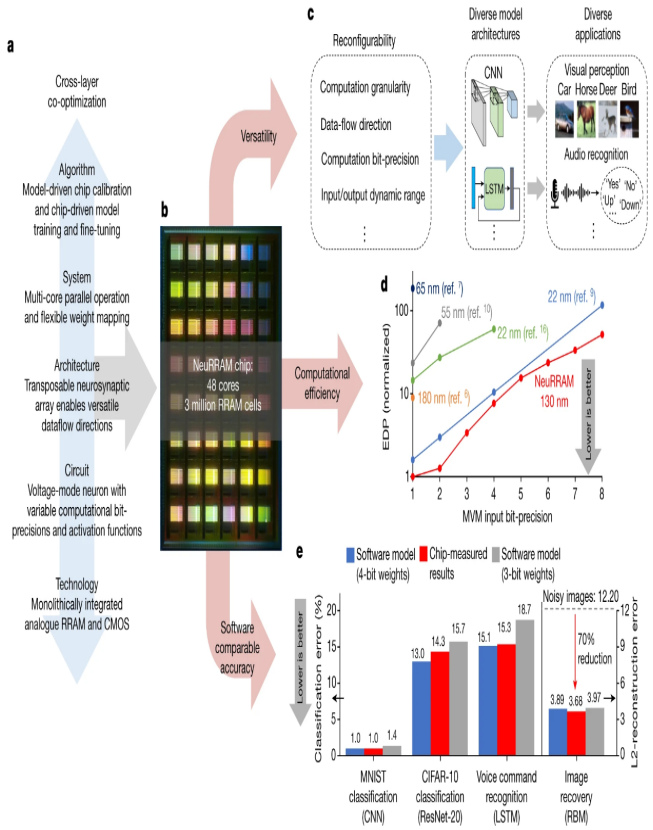
Common carbon footprint benchmarks

in lbs of CO2 equivalent

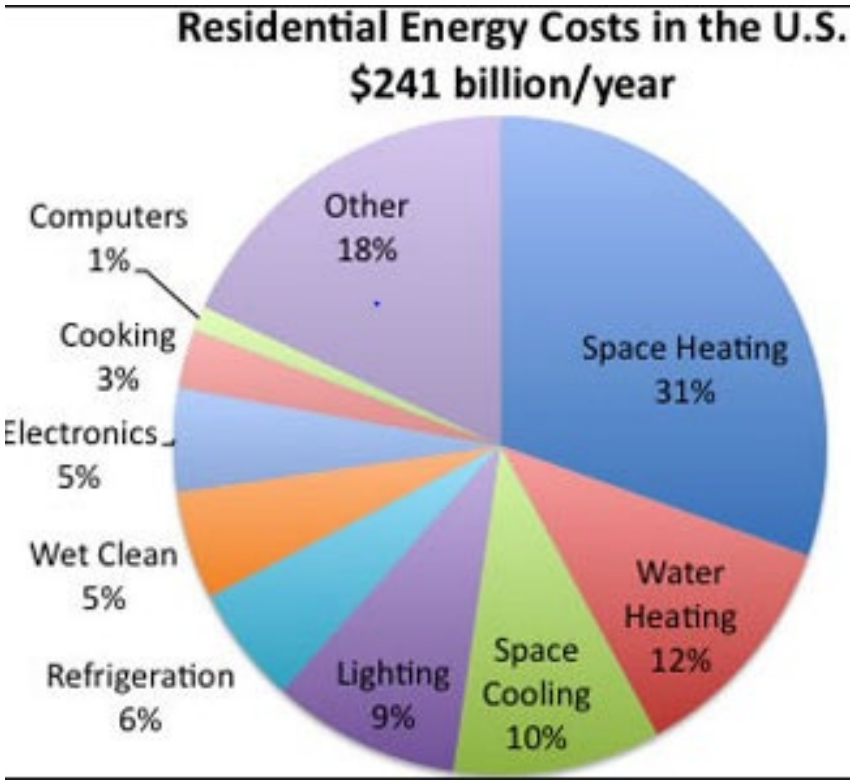


	Date of original paper	Energy consumption (kWh)	Carbon footprint (lbs of CO2e)	Cloud compute cost (USD)
Transformer (65M parameters)	Jun, 2017	27	26	$41-$140
Transformer (213M parameters)	Jun, 2017	201	192	$289-$981
ELMo	Feb, 2018	275	262	$433-$1,472
BERT (110M parameters)	Oct, 2018	1,507	1,438	$3,751-$12,571
Transformer (213M parameters) w/ neural architecture search	Jan, 2019	656,347	626,155	$942,973-$3,201,722
GPT-2	Feb, 2019	-	-	$12,902-$43,008

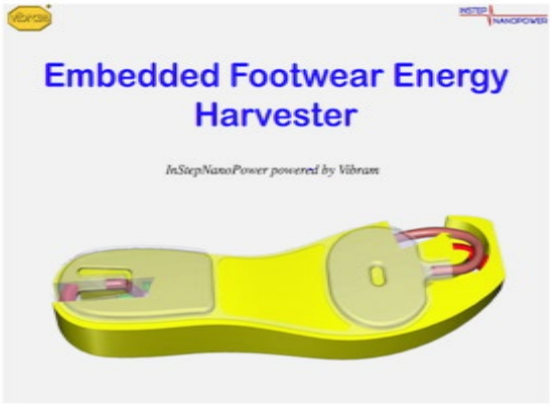
From: A compute-in-memory chip based on resistive random-access memory



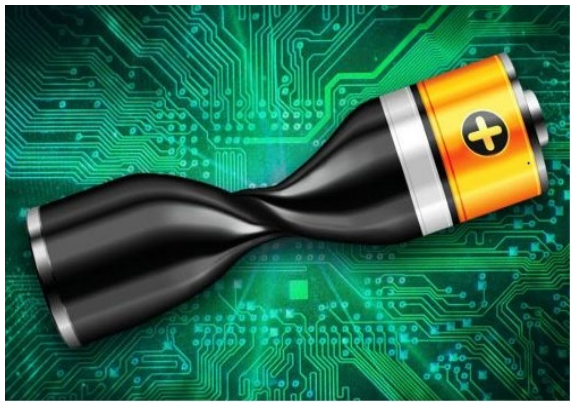
Home Electronics Energy Usage Keeps Growing



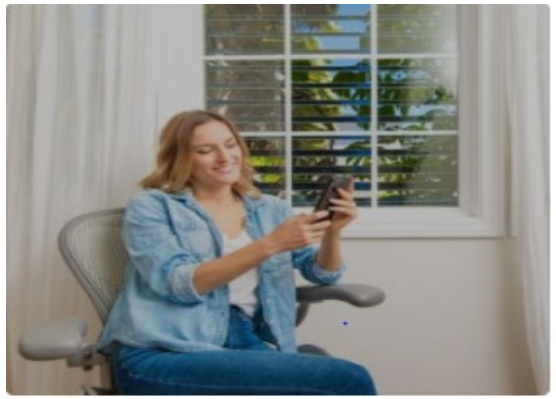
Energy Efficient Critical Ideas



Design of footwear



PowerShare: Power Transfer Interactions for Mobile Devices



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Solar Roadways

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