



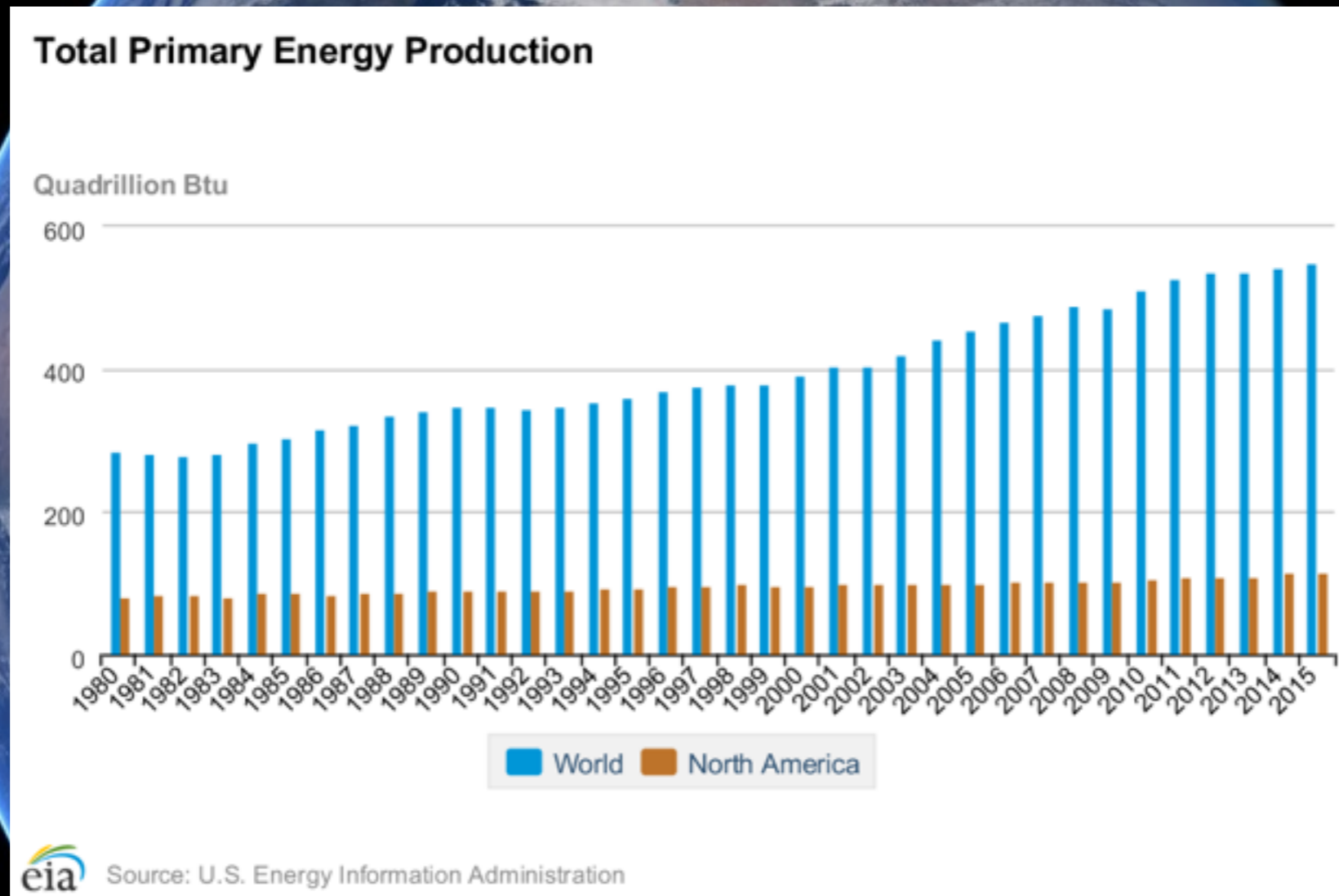
180TW



18 TW

TW GW MW kW W
18,000,000,000,000

TW
GW
MW
kW
W
18,000,000,000,000



Source: EIA Total World Primary Energy Production
~550 Quadrillion BTUs / 1 year = 1.8×10^{13} Watts

See notes from [MacKay](#) and [EIA](#) on conversions when aggregating disparate energy sources.

TW GW MW kW W
18,000,000,000,000 1

1W

TW GW MW kW W
18,000,000,000,000,000 1

Smil's "orange on the table" example:

$$((.1 \text{ kg}) * (10 ((\text{m} / \text{s}) / \text{s})) * (1 \text{ m})) / (1 \text{ s}) =$$

1 watt



TW GW MW kW W
18,000,000,000,000,000,000 1

Smart phone use:

~10 watt-hour battery typical, ~10 hours active use =

~1 Watt



Apple battery capacities in Watt-hours

iPhone 8 Plus: 10.28 Wh

<https://images.apple.com/legal/more-resources/docs/apple-product-information-sheet.pdf>

Detailed phone energy analysis:

https://www.usenix.org/legacy/event/atc10/tech/full_papers/Carroll.pdf

TW
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10

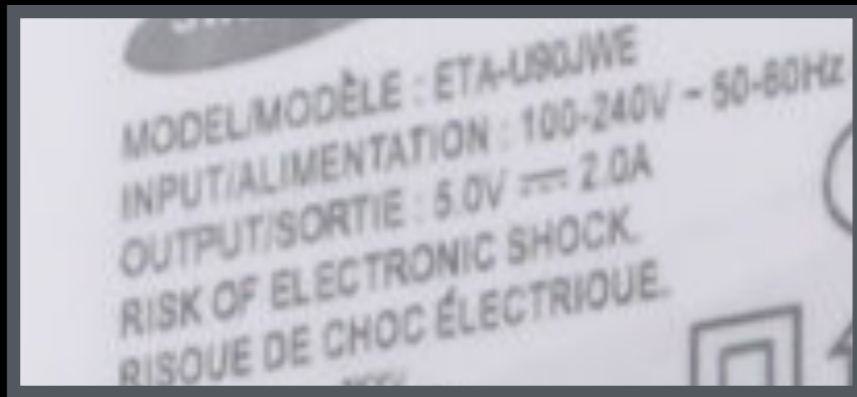
10W

TW GW MW kW W
18,000,000,000,000,010

Small Device Charging

5 Volts * 2 Amps

~10 Watts



TW GW MW kW W
18,000,000,000,000,000,000 10

Laptop use

~100 Watt-hour battery / 10 hours =

~10 Watts



Apple battery capacities in Watt-hours
A1398 MacBook Pro 15" (2015) : 99.5 Wh

<https://images.apple.com/legal/more-resources/docs/apple-product-information-sheet.pdf>

TW GW MW kW W
18,000,000,000,000,100

Small electric scooter:

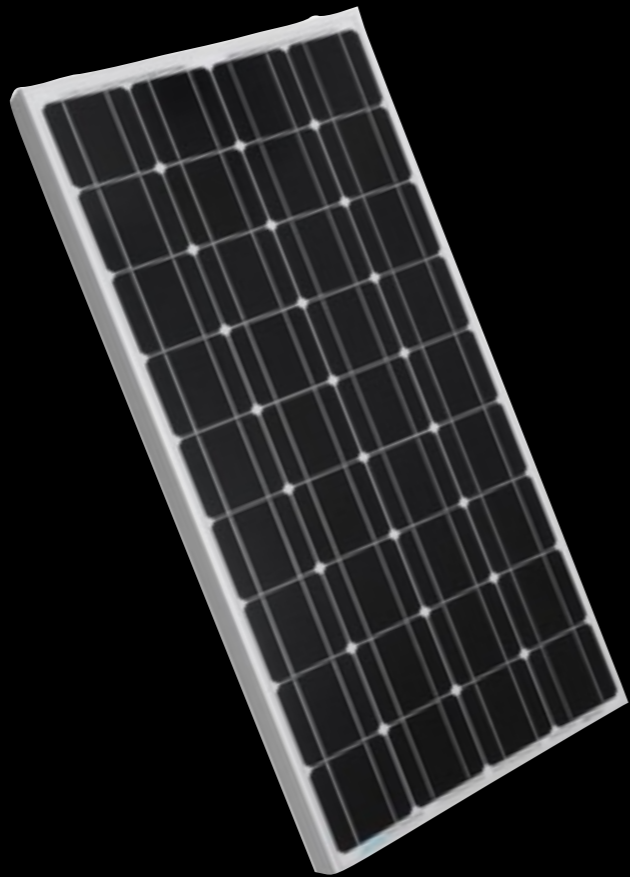
~100 Watts



TW GW MW kW W
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Medium-sized solar panel

~100 Watts

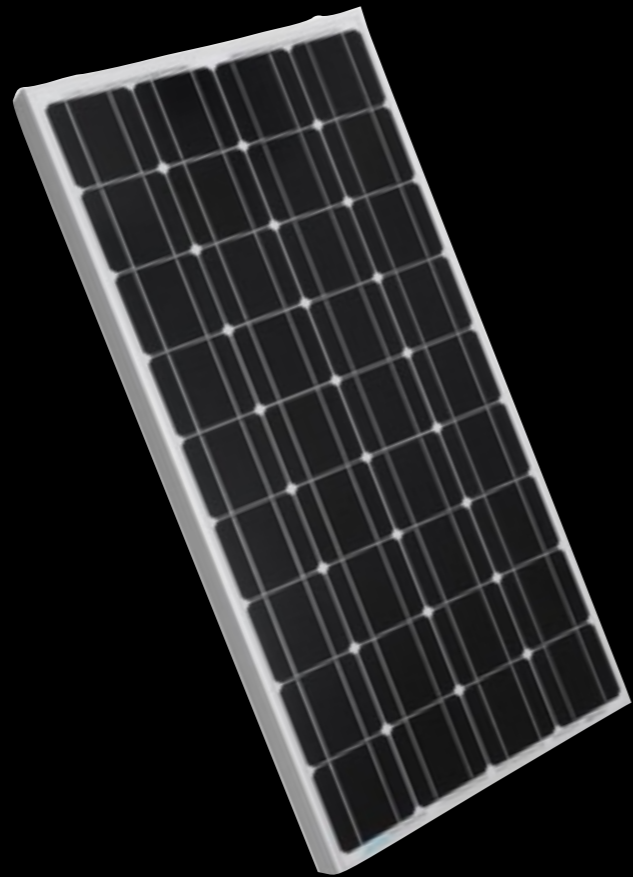


TW GW MW kW W
18,000,000,000,000,000 100

Human

2000 kilocalories / 1 day =

~100 Watts



TW GW MW kW W
18,000,000,000 1,000

1kW

TW GW MW kW W
18,000,000,000 1,000

Small kitchen appliance in use:
~1000 Watts (1 kW)



1000W Microwave

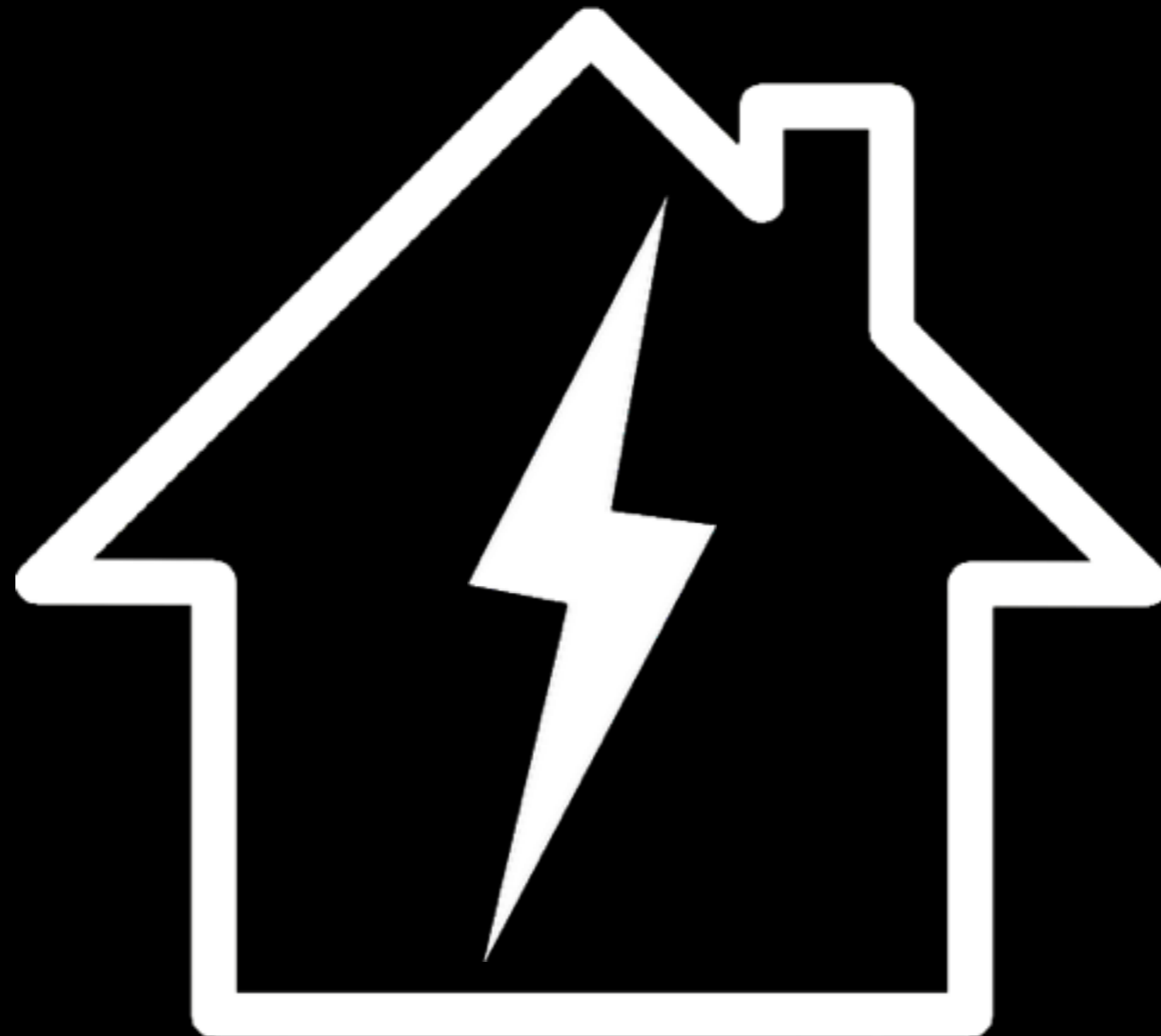


1000W Toaster

TW GW MW kW W
18,000,000,000 1,000

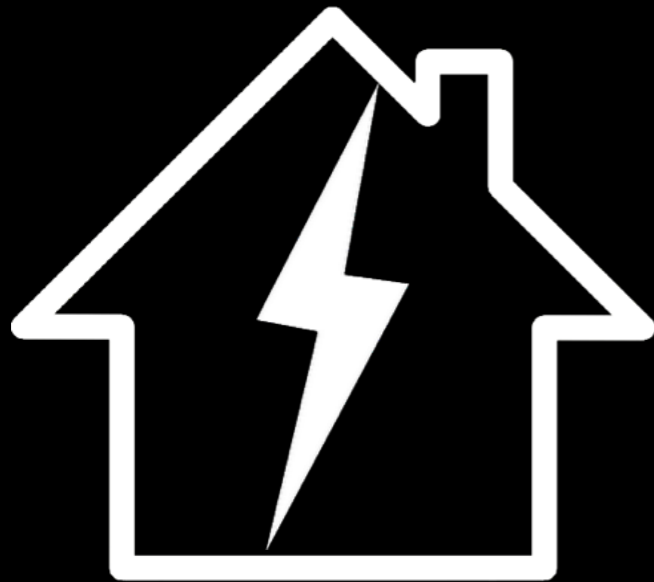
Average US whole-home **electricity** use:

~1000 Watts (1 kW)



TW GW MW kW W
18,000,000,000 1,000

Average US whole-home **electricity** use:
~1000 Watts (1 kW)



Source: EIA "In 2016, the **average annual** electricity consumption for a U.S. residential utility customer was **10,766 kWh**, an average of 897 kWh per month. Louisiana had the highest annual electricity consumption at 14,881 kWh per residential customer and Hawaii had the lowest at 6,061 kWh per residential customer."

US Average:

$$(10,800 \text{ kilowatt hours}) / (1 \text{ year}) = 1230 \text{ watts}$$

Louisiana:

$$(14,900 \text{ kilowatt hours}) / (1 \text{ year}) = 1700 \text{ watts}$$

Hawaii:

$$(6,000 \text{ kilowatt hours}) / (1 \text{ year}) = 685 \text{ watts}$$

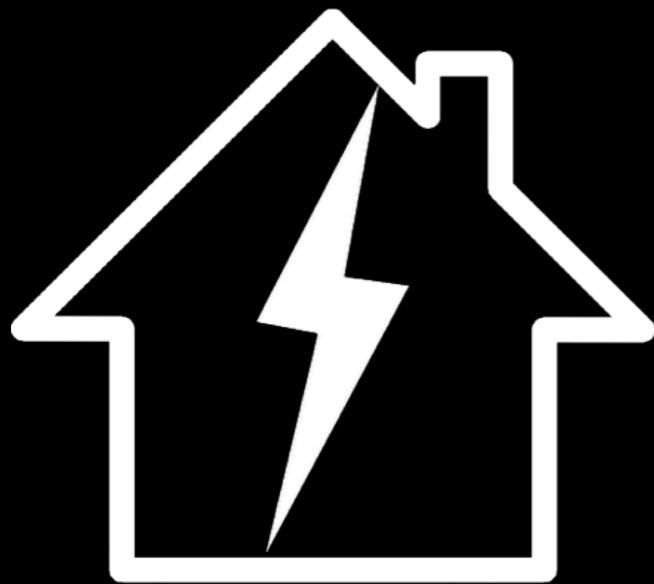
\$.08/kWh

\$.26/kWh

TW GW MW kW W
18,000,000,000 1,000

Average US whole-home **electricity** use:

~1000 Watts (1 kW)



US Average:

(10,800 kilowatt hours) / (1 year) =
1230 watts

Jeff: *\$.14/kWh*

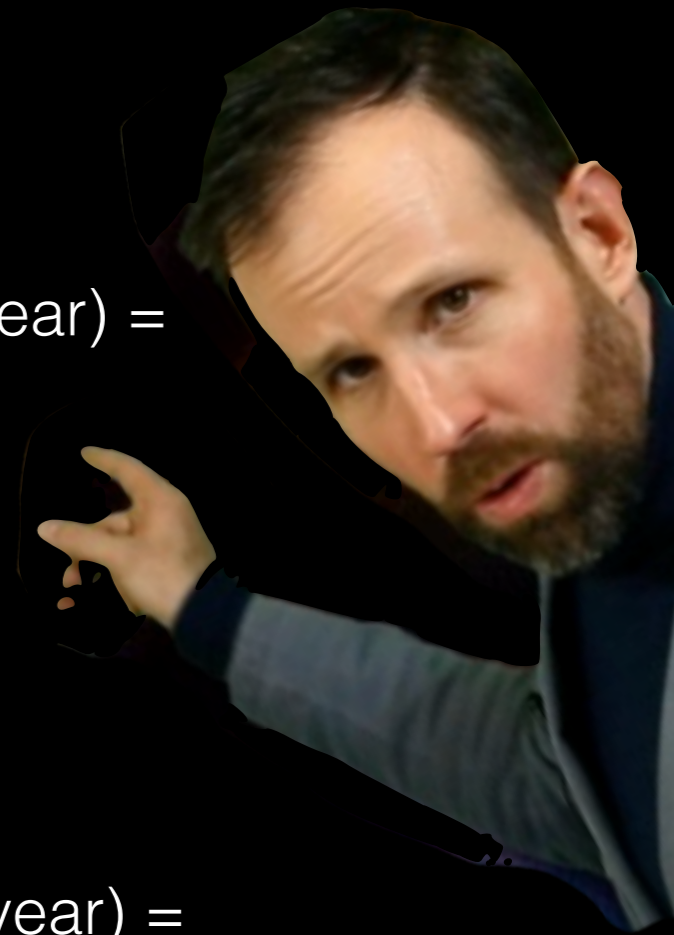
(6,429 kilowatt hours) / (1 year) =
733 watts

Louisiana:

(14,900 kilowatt hours) / (1 year) =
1700 watts

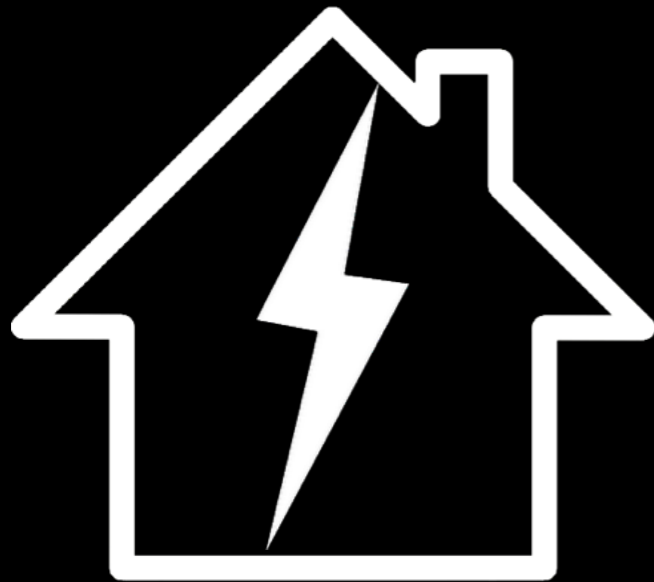
Hawaii:

(6,000 kilowatt hours) / (1 year) =
685 watts

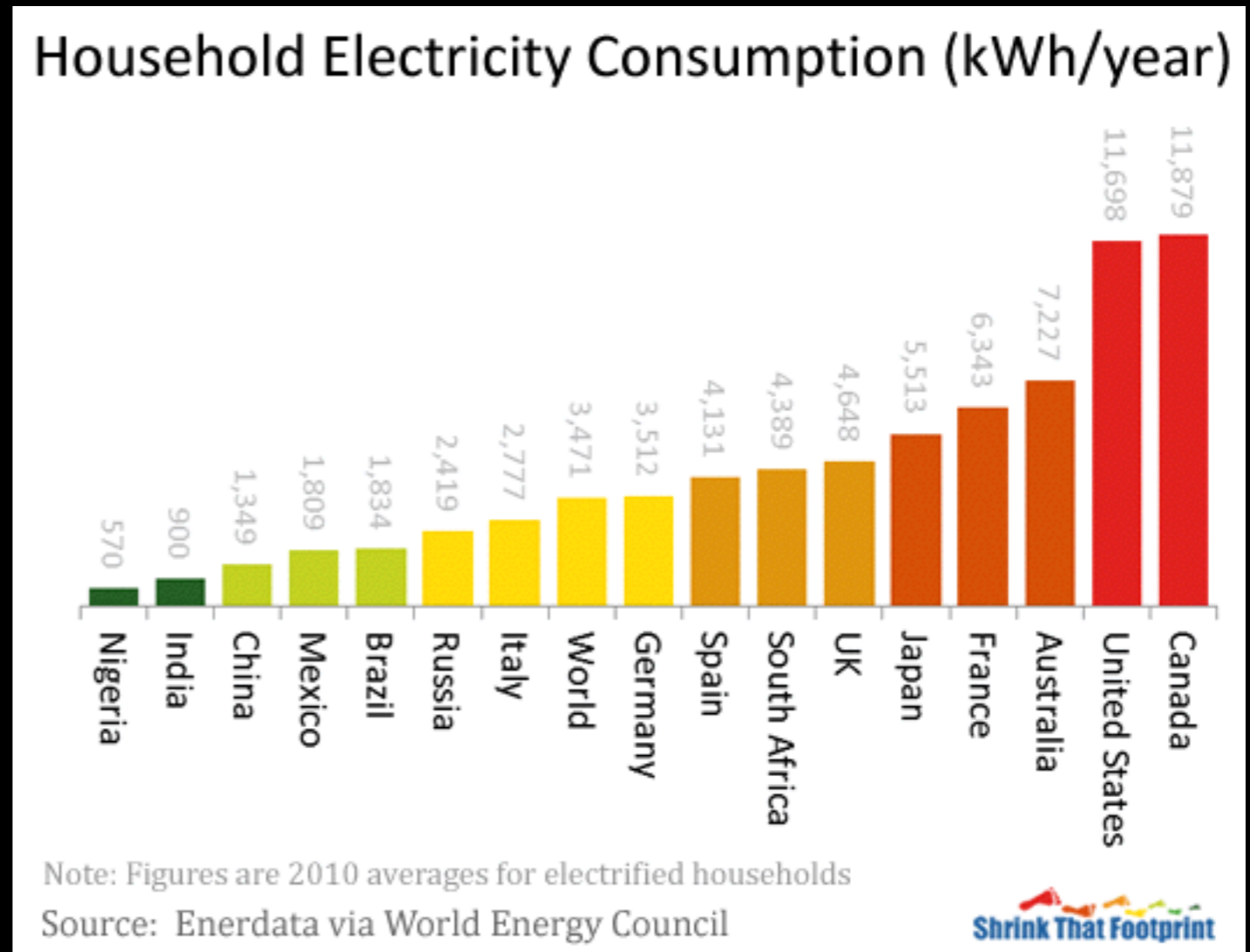


TW
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18,000,000,000 1,000

Average US whole-home **electricity** use:
~1000 Watts (1 kW)

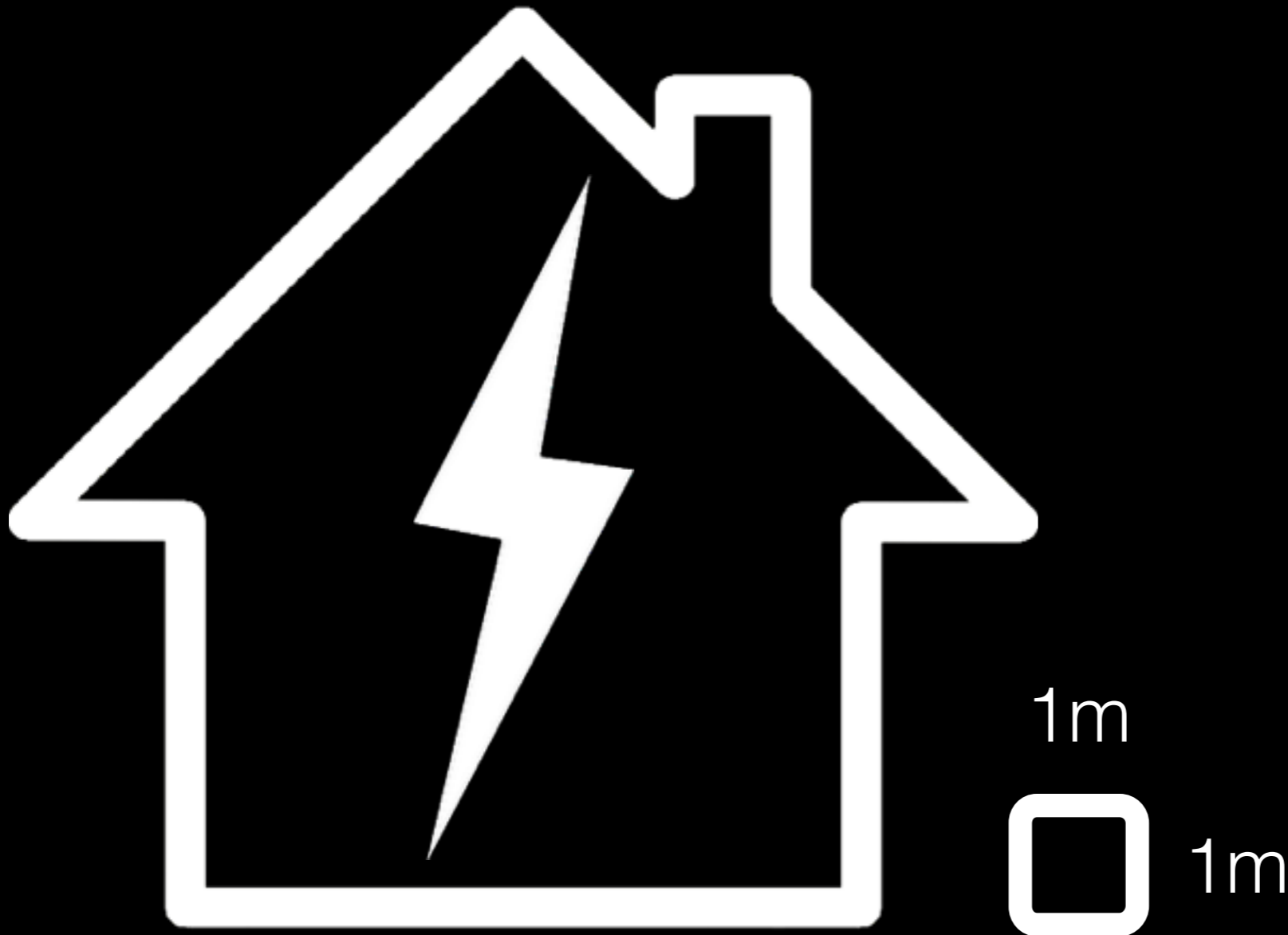


US Average:
 $(10,800 \text{ kilowatt hours}) / (1 \text{ year}) = 1230 \text{ watts}$



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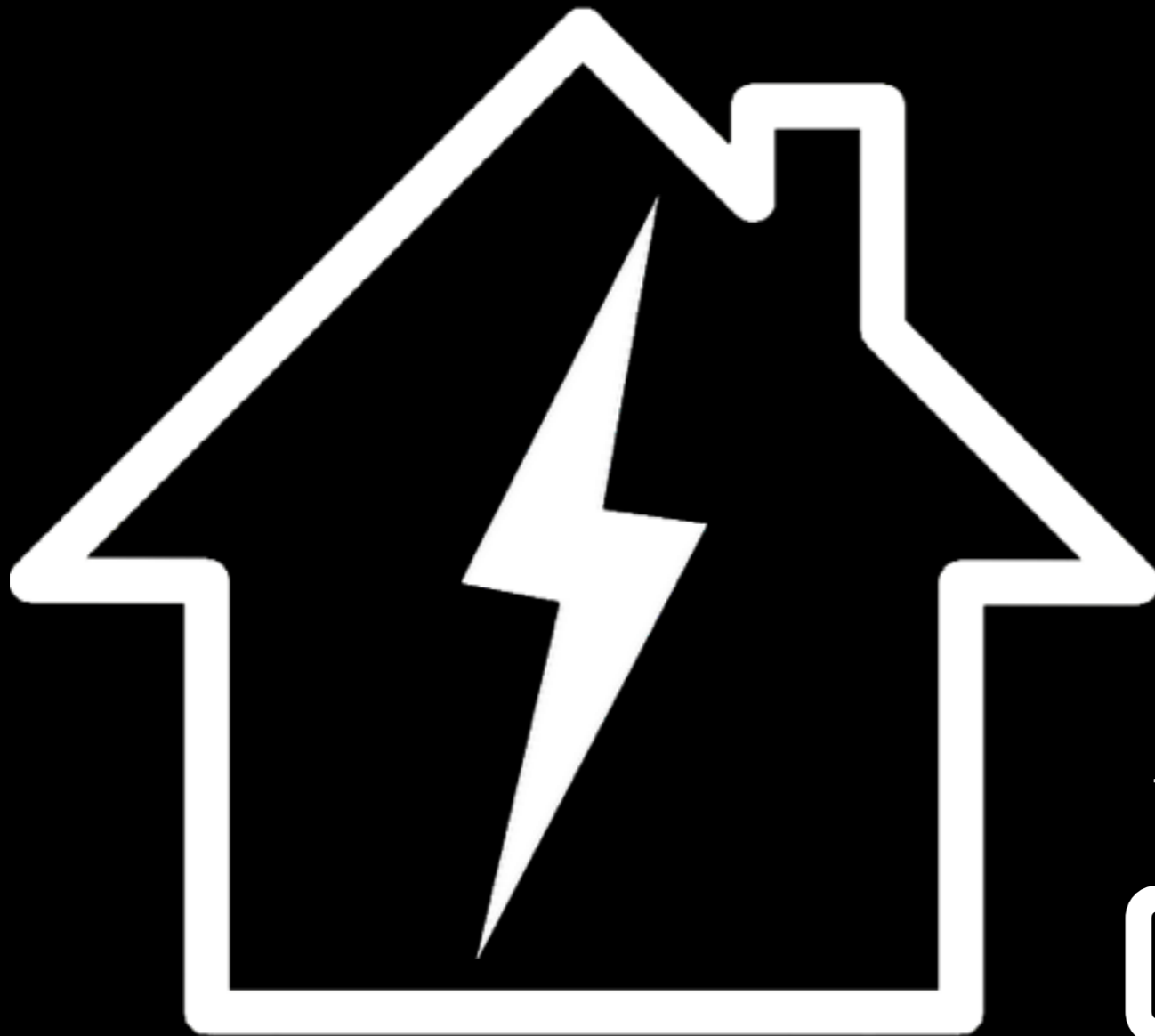
Solar flux through 1 square meter*
~1000 Watts (1 kW)



*AM1.5 standard

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1,000,000,000
kW
1,000
W

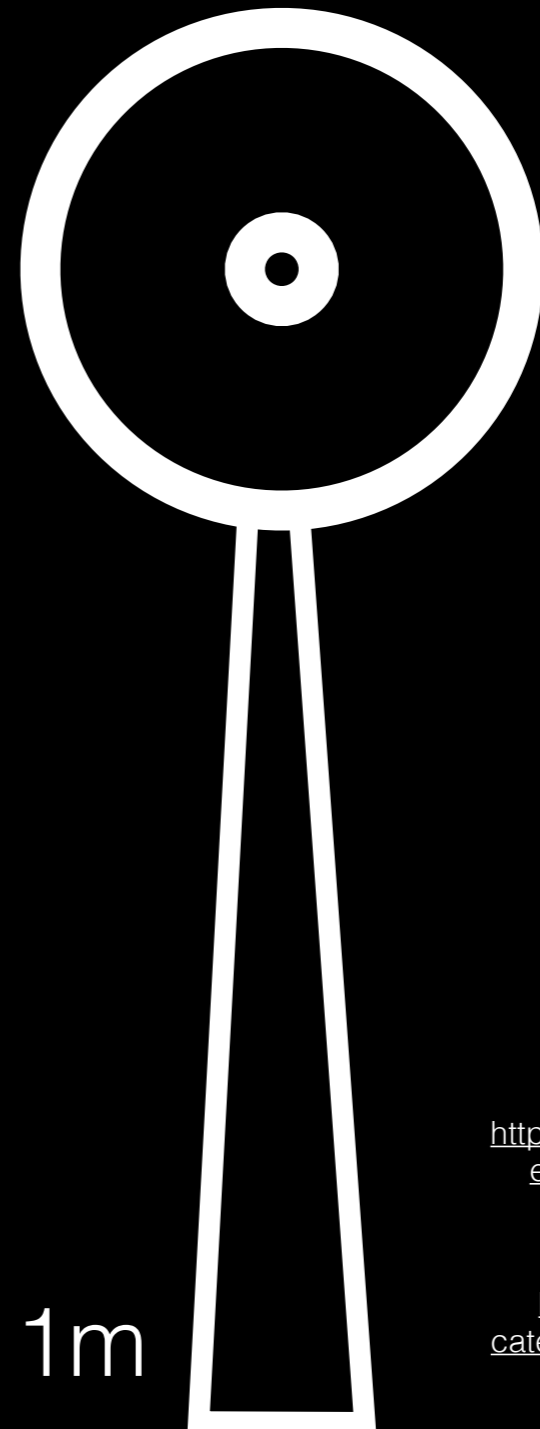
2-3m wind turbine in strong wind
~1000 Watts (1 kW)



1m



1m



2-3m

<https://www.solar-electric.com/pika-energy-t701-wind-turbine.html>

<https://www.emarineinc.com/categories/Airdolphin-Marine-Wind-Turbine-1000-Watt>

TW GW MW kW W
18,000,000,000 10,000

10kW

TW GW MW kW W
18,000,000,000 10,000

Large roof covered in solar panels
~10kW peak output



40 250W panels

TW GW MW kW W
18,000,000,000 10,000

300 Amp welder
~10kW



TW GW MW kW W
18,000,000,000,000,000 10,000

Personal Share of All US Energy
Consumption

100 Quadrillion BTUs / 1 year / 320 Million people

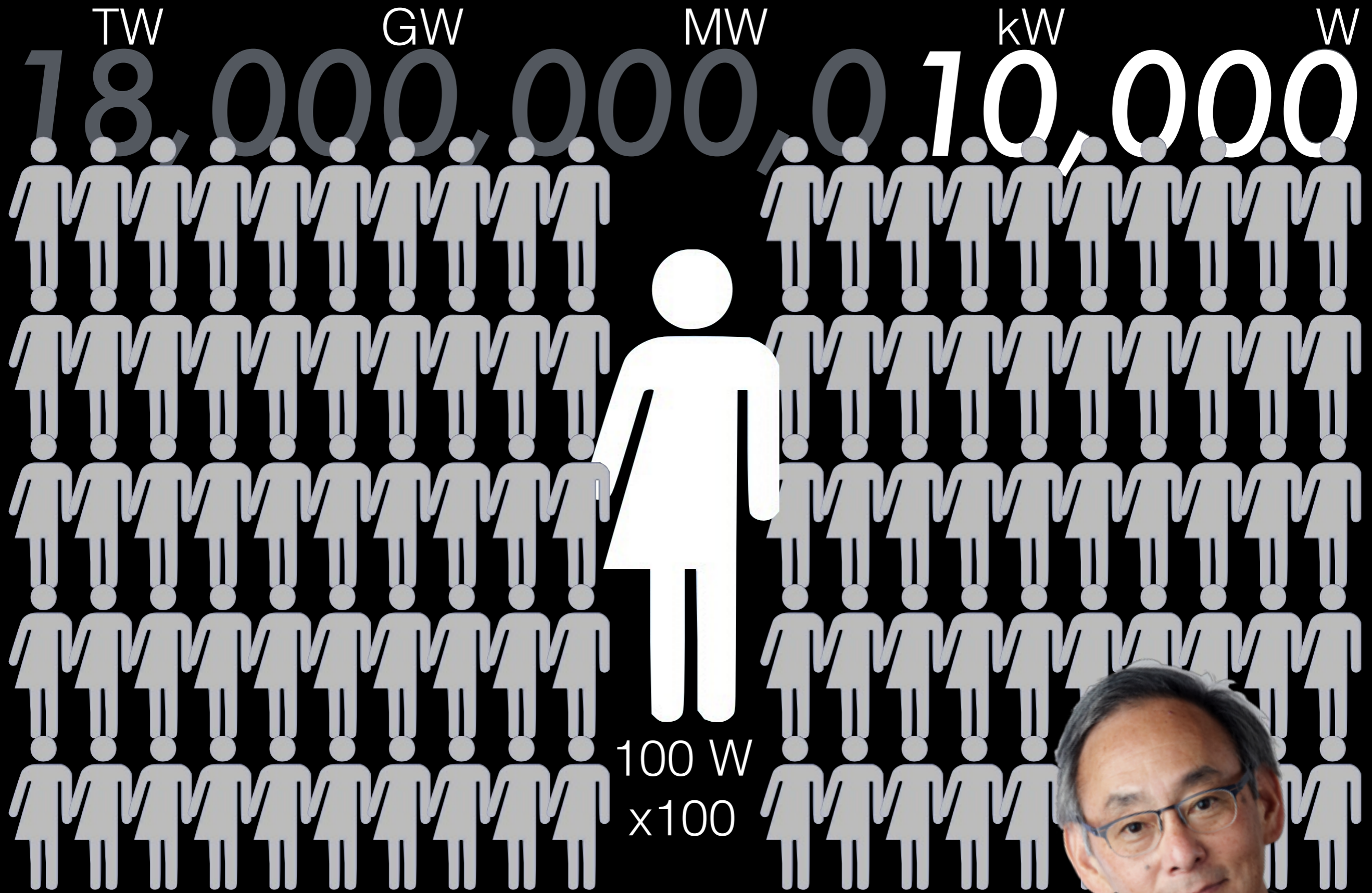
~10kW



TW
18,000,000,000
GW
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kW
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10,000



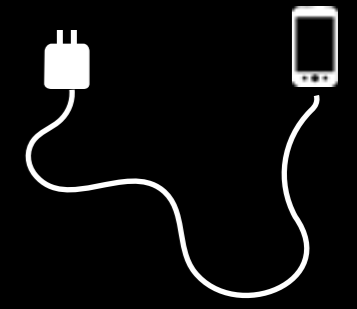
*“Every person in the United States uses energy as if they had **100 personal servants** at their beck and call” - Obama Energy Secretary Steven Chu in 2009*



*“Every person in the United States uses energy as if they had 100 personal **servants** at their beck and call” - Obama Energy Secretary Steven Chu in 2009*



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GW
10,000
MW
10,000
kW
10,000
W
10,000



Watts:

10,000

1,000

100

10

1

Stop here for today,
Jeff