Answers to the “Homework Assignment”

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Per-Year Electric Energy (MWh) per Capita

	2010	2019	Decrease or Increase	
Canada	15.15	15.02	-0.13	(-0.8%)
USA	13.36	12.74	-0.62	(-4.6%)
Japan	8.40	**7.94**	-0.46	(-5.5%)
France	7.76	7.04	-0.72	(-9.2%)
Germany	7.22	6.61	-0.61	(-8.5%)
UK	5.74	4.75	-0.99	(-17.2%)
Italy	5.38	5.21	-0.18	(-0.3%)
China	2.96	5.12	+2.16	(+73.1%)
World Average	2.89	3.27	+0.38	(+12.9%)

IEA World Energy Balances 2021

Electric power per capita in Japan

7.94 MWh / 8760 h = 0.91 kW per capita

Difference in R & D Period between PE and PEL

R & D: Research & Development

PE: Power Engineering in a narrow or traditional sense

PEL: Power Electronics

R & D	PE	PEL
Immediate period:	5-10 years	1-2 years
Short period:	10-20 years	2-5 years
Middle period:	20-40 years	5-10 years
Long period:	40-70 years	10-30 years

Roadmaps for PE and PEL people

Toward 2050 : valuable for both PE and PEL

Toward 2100 : acceptable for PE but unacceptable for PEL

Answer to Question 1

- What will be the total energy needed by humanity in 2050?

Per-year world-average electric energy per capita:

3.27 MWh in 2019 (from IEA World Energy Balances 2021)

This fact enables to estimate the energy in 2050 as 5 MWh

Let a world-average electrification rate in 2050 be 14%,

(estimated from IEA World Energy Balances 2021)

Thus, 10-billion (= 10^{10}) humans in 2050 will consume the following total energy on the globe:

5 MWh $\times 10^{10} / 0.14 = 3.6 \times 10^{17}$ Wh per year, or

0.98×10^{15} Wh per day (= 3.5×10^{18} J per day)

Answer to Question 2

- If all the energy will be carbon-free, how much of those needs will be provided through electricity?

Electrification rate: Electric energy / Final energy

	2019		2050
Japan:	25.8%	→	40%?
USA:	20.7%	→	35%?
Germany:	19.4%	→	35%?

IEA World Energy Balances 2021

Answer to Question 3

- What could be the best electrical energy system for generating, transporting and supplying all that electricity globally?

Akagi's comment:

Should be answered region by region or county by country.

As an example, Japan

- depends on the best mix among coal, natural liquefied gas, oil, and uranium for energy security.
- has been active in the enhancement of energy savings and in the use of renewable energy.
- has no internationally-tied power transmission line.

Answer to Question 4

- What power electronics technology advances are necessary for the envisioned global energy system?

- Breakthroughs or further significant improvements in active switching devices (SiC-MOSFETs, GaN-HEMT, Ga_2O_3-FETs, and so on), passive components, cooling devices and systems, energy storage devices, *etc*.

  (Dr. Takashi Mimura invented the HEMT structure in 1979. He received the Kyoto Prize in 2017.)

- High-power medium-voltage power conversion systems
  1) for producing hydrogen and e-fuel (electro-fuel)
  2) for replacing a blast furnace with an arc furnace, which would reduce CO_2 emission by 75%.