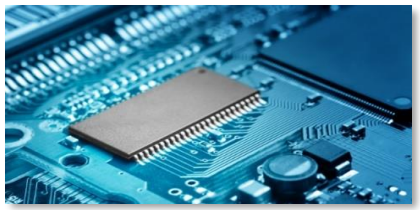
Role of the Nuclear in Korean Energy Mix and Expected Roles in Net-Zero

September 18, 2024

Bum-Jin CHUNG
Kyung Hee University, KOREA

Energy Imports of Korea

- Korea lacks natural resources including renewable resources
  - imports 95% of energy
  - corresponds to 25% national import
  - corresponds to the profits from semiconductor and auto exports



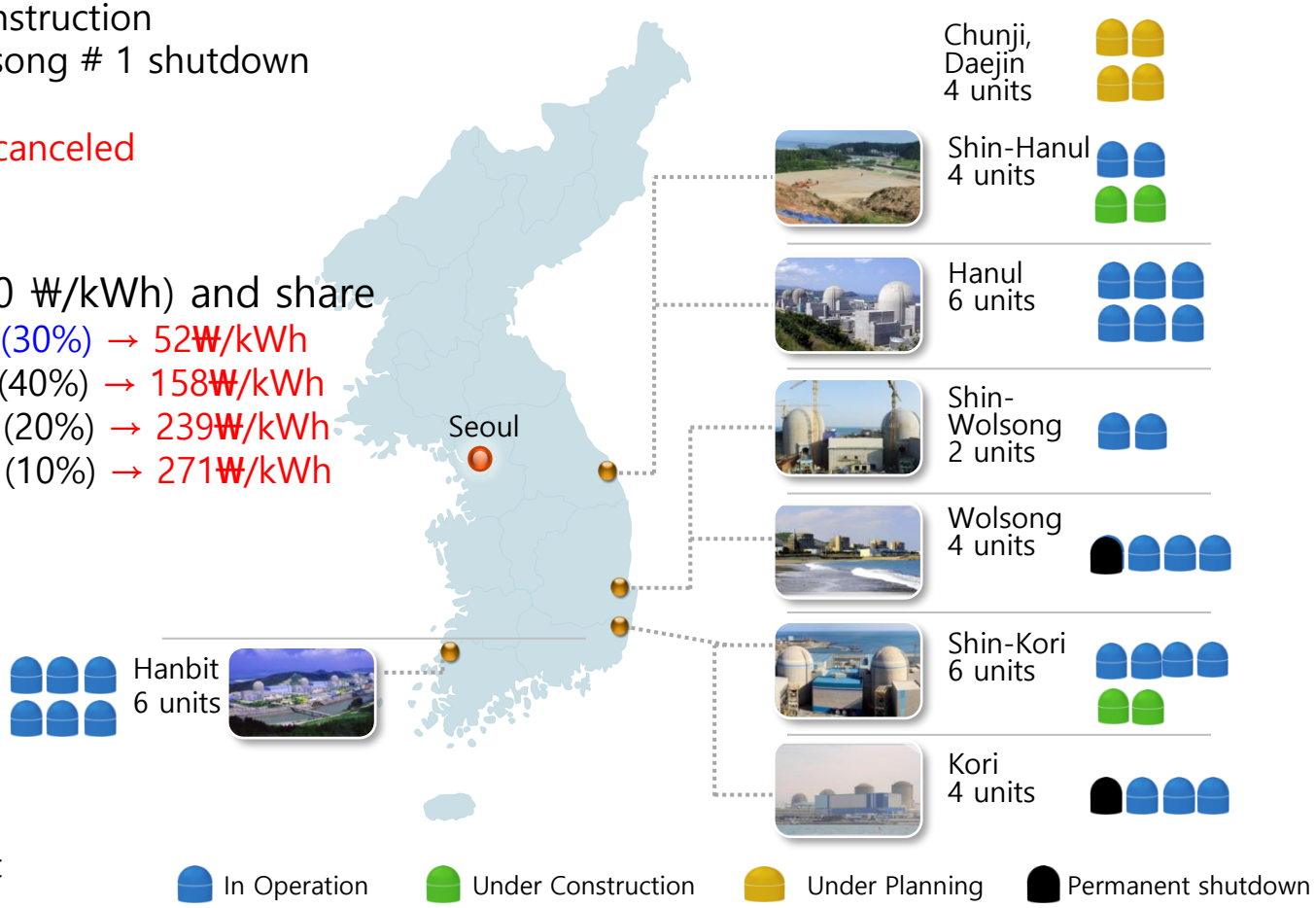
- Annual Energy Imports (billion$)
  - 2014: 143.6
  - 2015: 102.7
  - 2016: 80.9
  - 2017: 109.5
  - 2022: 217.2
  - 2023: 170.3

Breakdown (%) (2015, 2019)
- Oil: 73.1 72.0
- LNG: 18.8 16.3
- Coal: 9.9 11.2
- Uranium: 0.9 0.6

Nuclear Power Plants in Korea

26 NPPs in operation (2024)
- 4 units under construction
- Kori #1 and Wolsong # 1 shutdown permanently
- 4 planned NPPs canceled

Electricity cost (~110 ₩/kWh) and share
- Nuclear ~60 ₩/kWh (30%) → 52₩/kWh
- Coal ~80 ₩/kWh (40%) → 158₩/kWh
- LNG ~120 ₩/kWh (20%) → 239₩/kWh
- Others ~200 ₩/kWh (10%) → 271₩/kWh



Yongkwang→ Hanbit
Uljin → Hanul

Korean Nuclear Energy at a Glance

1958
Enactment of Atomic Energy Act

1959
Establishment of Office of Atomic Energy & Atomic Energy Research Institute

1962
Construction of **The first** Research Reactor, TRIGA Mark II

1970
Introduction of Nuclear Power Construction of Kori Unit 1 ('71~78)

1980
Establishment of Localization Plan ('84)

1990
Technology Self-Reliance Development of OPR1000

2000
Advanced Reactor Development of APR1400 and SMART

2009
Won contracts for a JRTR in Jordan, and 4 APR1400 in the UAE (Successful construction)

2011
Establishment of Nuclear Safety and Security Commission (NSSC)

2012
Acquired Standard Design Approval for SMART

2015
Signed SMART PPE with Saudi

2024
Preferred Negotiator for Czech's Dukovany 5&6

Korean Nuclear Power Plant Export

- UAE Export 2009 (4 Barakah units)
- Economic competitiveness

Table 8.2: Construction costs of recent FOAK Generation III/III+ projects

Type	Country	Unit	Construction start	Initial announced construction time	Ex-post construction time	Power (MWe)	Initial announced budget (USD/kWe)	Actual construction cost (USD/kWe)
AP 1000	China	Sanmen 1, 2	2009	5	9	2 x 1 000	2 044	3 154
	United States	Vogtle 3, 4	2013	4	8/9*	2 x 1 117	4 300	8 600
APR 1400	Korea	Shin Kori 3, 4	2008	5	8/10	2 x 1 340	1 828	2 410
EPR	Finland	Olkiluoto 3	2005	5	16*	1 x 1 630	2 020	>5 723
	France	Flamanville 3	2007	5	15*	1 x 1 600	1 886	8 620
	China	Taishan 1, 2	2009	4.5	9	2 x 1 660	1 960	3 222
VVER 1200	Russia	Novovoro-nezh II-1 & 2	2008	4	8/10	2 x 1 114	2 244	**

* Estimate. ** No data available.

- EU Requirement (Sep. 26, 2017)
- NRC Design Certificate (Aug. 26, 2019)
- UAE construction record : 'In-Time' 'Within Budget'
- Preferred Negotiator for Czech's Dukovany 5&6 (APR1000)

Role of the Nuclear in Korea

Table 4.10: Levelised costs of electricity for generating plants in Korea

Technology	Capital costs			O&M costs			Fuel, waste and carbon costs	Heat credit	LCOE		
	3%	7%	10%	3%	7%	10%			3%	7%	10%
	USD/MWh			USD/MWh			USD/MWh	USD/MWh	USD/MWh		
CCGT	7.03	11.29	15.04	5.55	5.55	5.55	109.24	0.00	121.82	126.08	129.82
CCGT	5.96	9.44	12.54	4.05	4.05	4.05	105.10	0.00	115.11	118.60	121.70
Coal – pulverised (PC 800)	7.54	13.70	19.34	5.31	5.31	5.31	64.81	0.00	77.66	83.83	89.46
Coal – pulverised (PC 1000)	7.47	13.53	19.17	4.80	4.80	4.80	62.03	0.00	74.30	80.36	86.00
Nuclear – ALWR	10.41	22.20	33.15	9.65	9.65	9.65	8.58	0.00	28.63	40.42	51.37
Solar PV – residential rooftop	127.69	189.06	241.31	27.86	27.61	27.45	0.00	0.00	155.56	216.67	268.76
Solar PV – commercial rooftop	100.61	148.96	190.13	21.95	21.75	21.63	0.00	0.00	122.56	170.71	211.75
Solar PV – large, ground-mounted	84.00	124.38	158.75	17.86	17.70	17.59	0.00	0.00	101.86	142.07	176.34
Onshore wind	82.78	118.58	149.77	28.86	28.86	28.86	0.00	0.00	111.64	147.45	178.63
Offshore wind	140.06	200.22	252.47	74.41	74.41	74.41	0.00	0.00	214.47	274.63	326.88

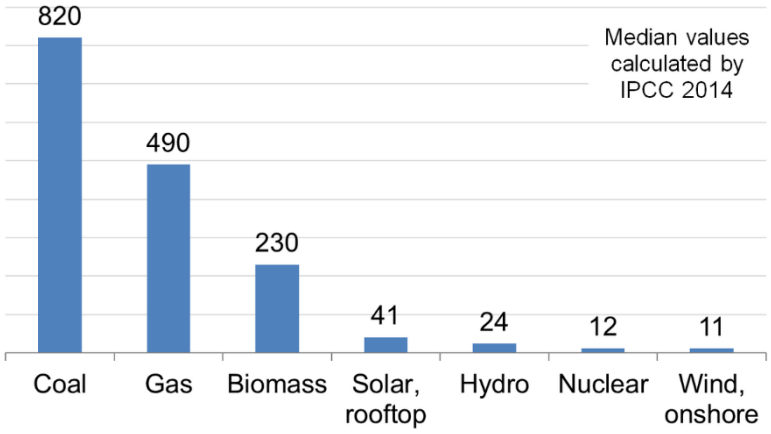
Energy Reserve **(Energy Security)**

- Oil : 3.5 months
- LNG : 1.5 months
- Coal : 0.5 months
- Nuclear : 18 months (+10 month)

Comparison

1g U^{235} 9 drum Oil 3 tons of coal

Lifecycle CO_2-equivalent emissions (g/kWh)



Independent Grid

Nuclear Exports

- JRTR in 2009

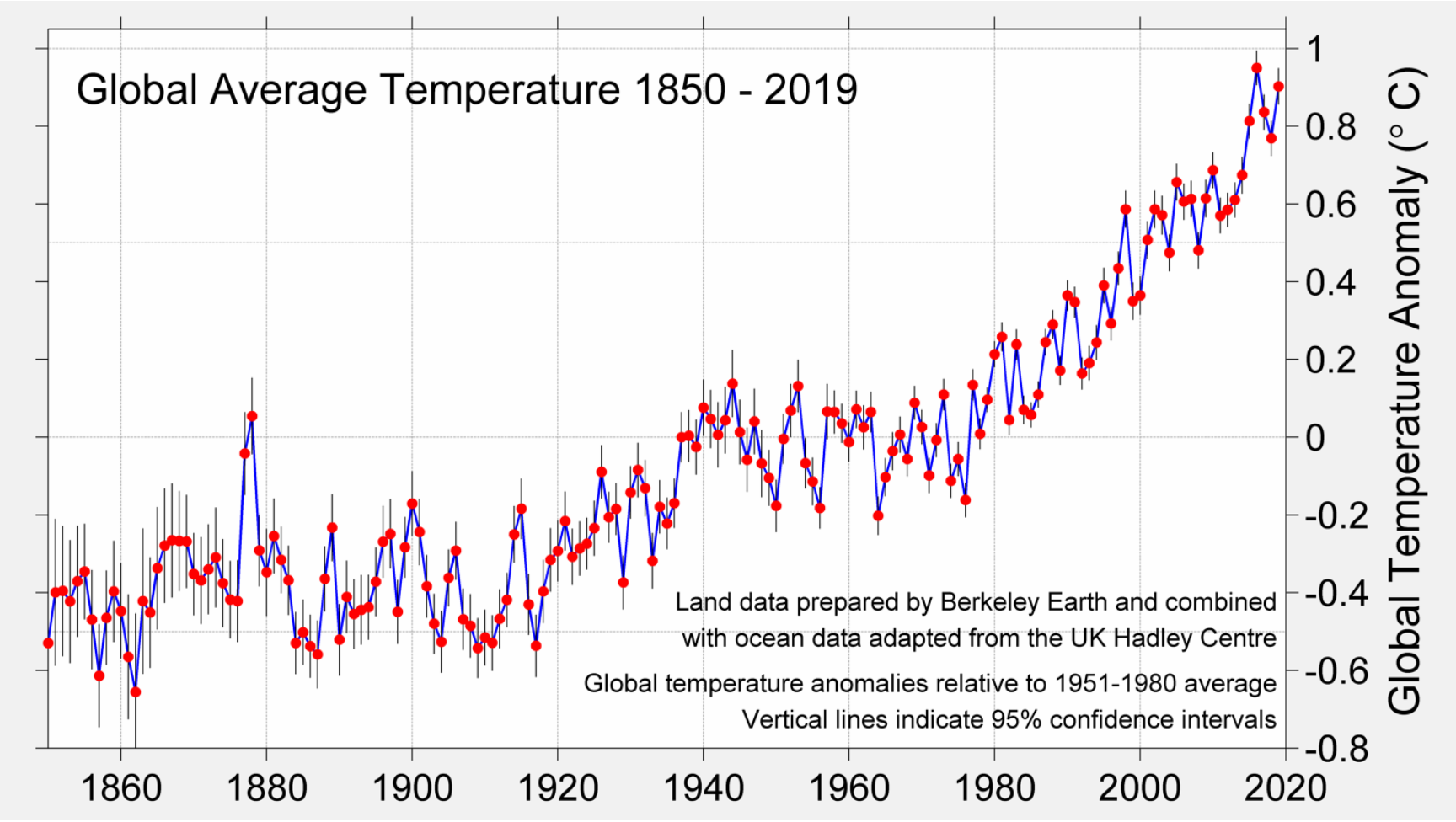
  Jordanian Research and Training Reactor

- Barakah NPPs in 2009

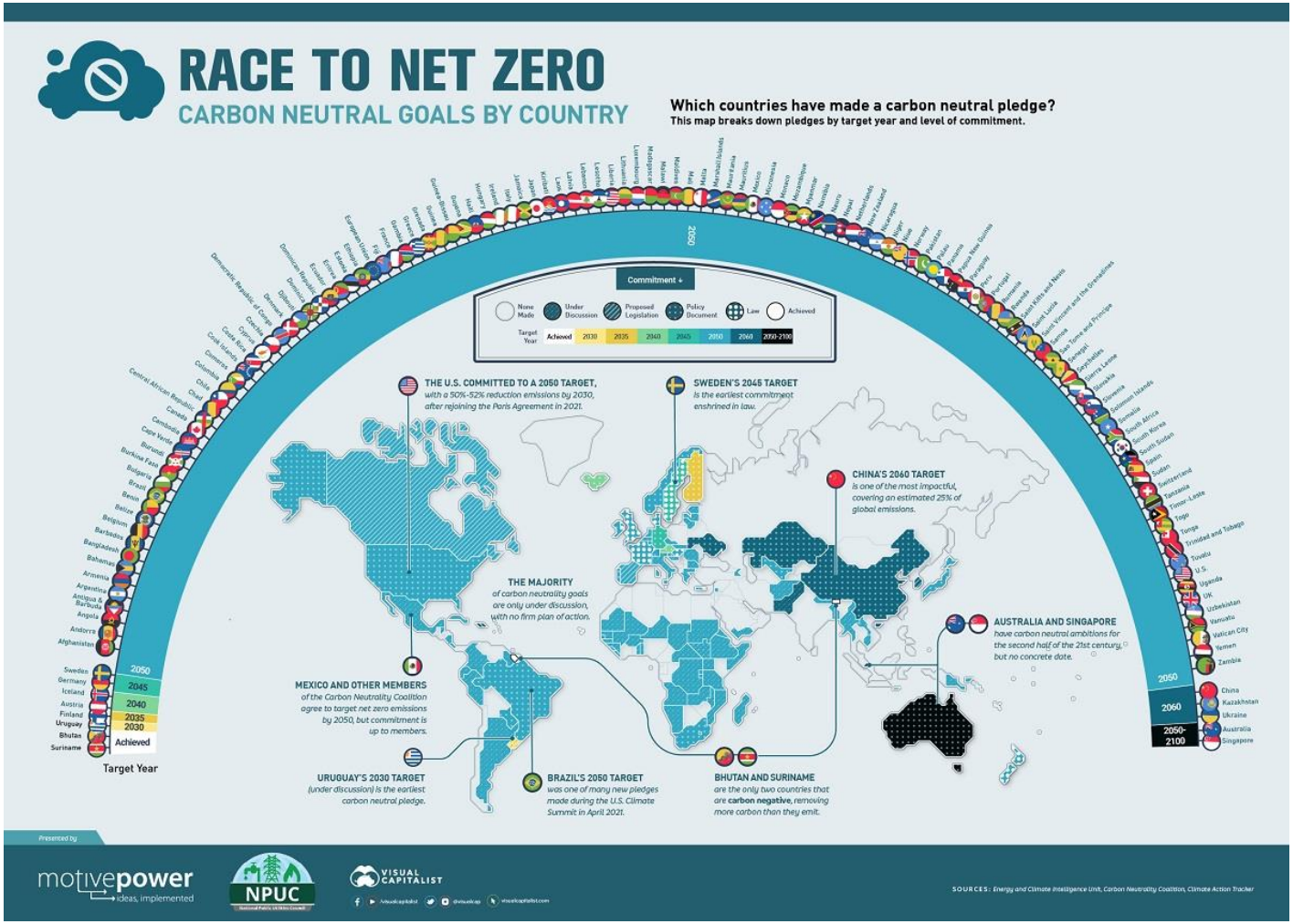
  (Exported with WH)

- Czech Dukovany 5&6 NPPs in 2024 (Preferred Negotiator)

Global Average Temperature



Race to Net-Zero



Net Zero Emission (CO_2 free)

- 2019 Energy consumption by form
  - Electricity (44.8 million TOE) from nuclear, coal, oil, LNG, renewables, etc
  - Fossil fuels (186.6 million TOE) from coal, oil, LNG, etc.

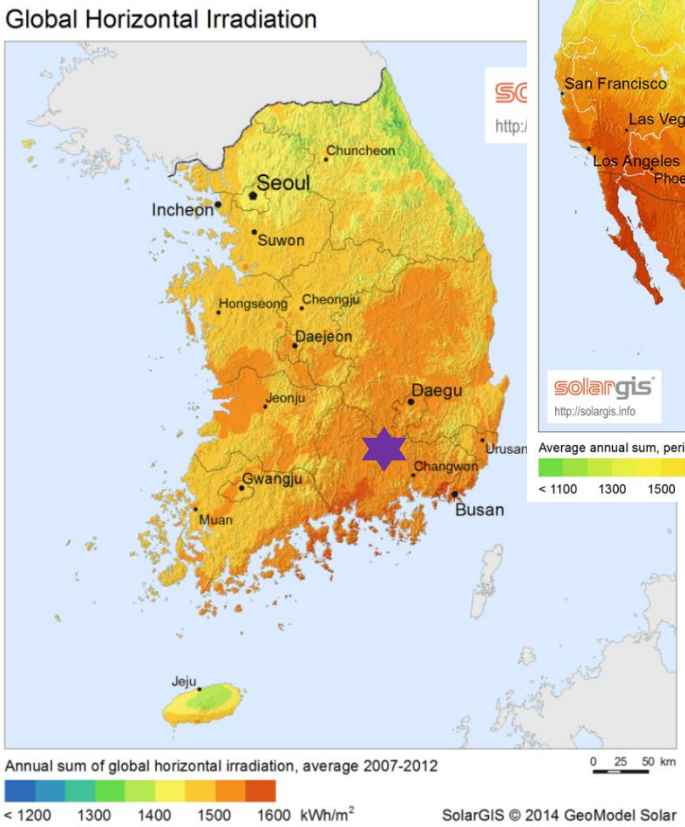
    → Net Zero required for Fossil fuels (4 times larger than electricity) as well.

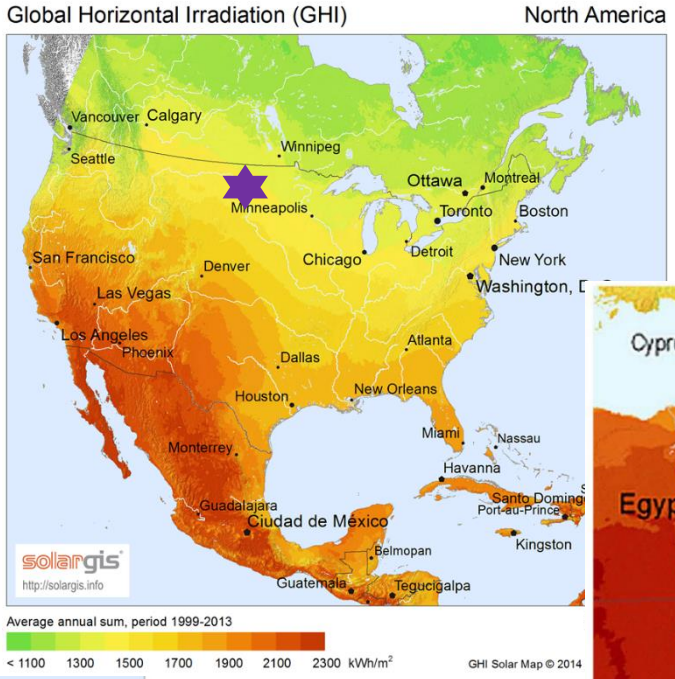
    → Transition to Electricity and/or Hydrogen (Carriers) required.

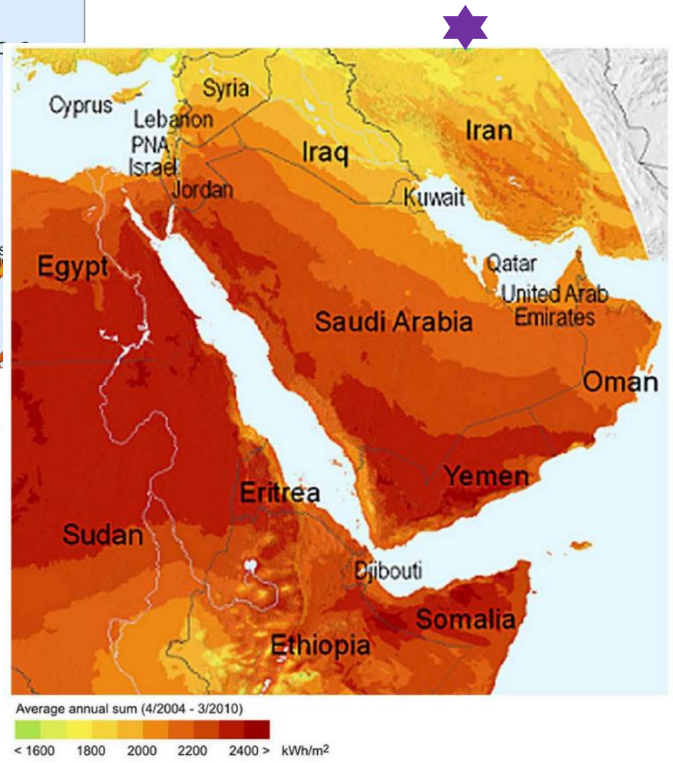
    (Carbon free electricity and Carbon free hydrogen?)
- 2019 Energy consumption by sector
  - Industry (142.9 million TOE), Transportation (43 million TOE), Home (22.6 million TOE), Commercial (17.5 million TOE), Public (5.4 million TOE)
  - Almost impossible to achieve NZE without sacrificing industry and commercial sectors (70%).
- 'Carbon Free 2050' Plan of Korea
  - Unrealistic (Renewable deployment, Hydrogen import, Super-grid connection,
  - Based on Nuclear Phase-out premise
  - Cost not calculated (Tremendous)

  → Possible only the renewables are substituted by nuclear.

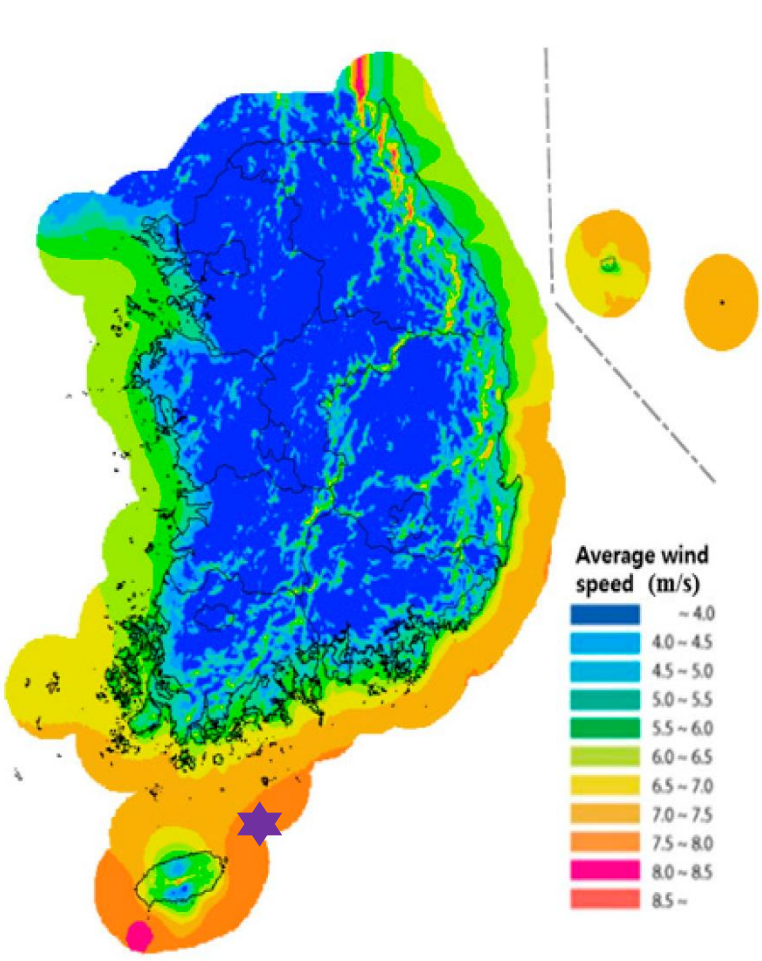
Solar resources

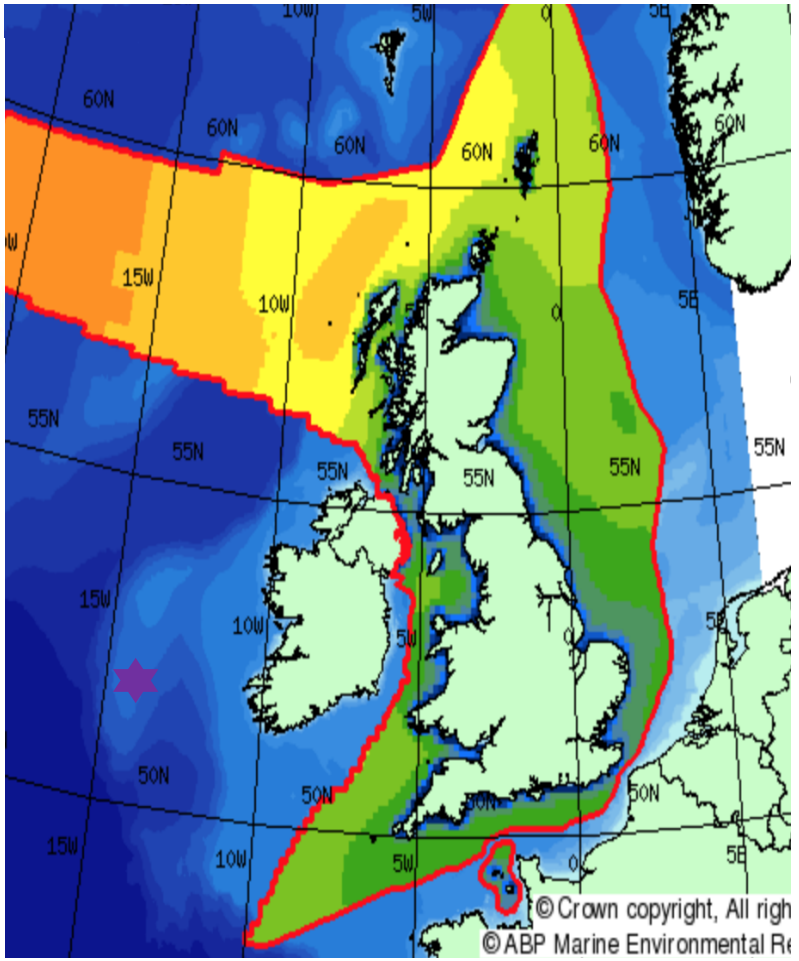


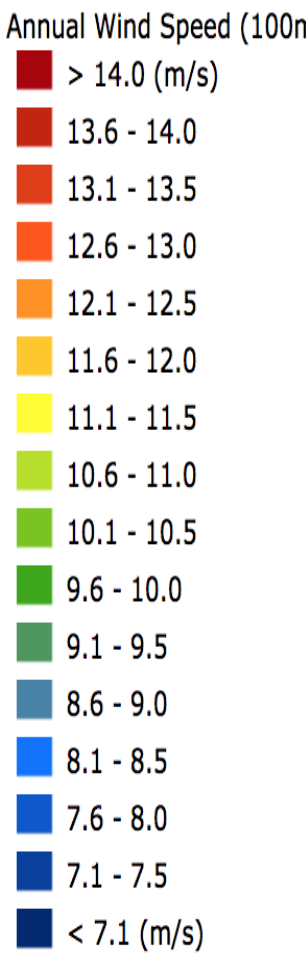




Wind resources







Awareness of Energy Security

- Russia's invasion of Ukraine (Feb.24, 2022)
- Gas cut-off from Russia
  - Retaliation against the Western helps to the Ukraine
  - Leaks of Nord Stream #1 and #2
  - Weaponization of gas supply
- European countries turned to the spot market
  - Europe is buying up fuel that used to go to developing countri
  - It boost other energy prices, putting international prices to new highs
- Demand increases in Europe
  - Recovering from the COVID-19 pandemic
  - Winter preparation (Gas storage to 90%)
- Insufficient supply to demand → Energy Crisis!

Microsoft is hiring a nuclear energy expert to help power its AI and cloud data centers

PUBLISHED MON, SEP 25 2023•12:49 PM EDT | UPDATED TUE, SEP 26 2023•8:34 AM EDT

Catherine Clifford
@IN/CATCLIFFORD/
@CATCLIFFORD

KEY POINTS

- Microsoft is looking to hire a "principal program manager for nuclear technology."
- Specifically, Microsoft is looking to hire someone to lead the company's technical assessment for integrating small modular nuclear reactors and microreactors "to power the datacenters that the Microsoft Cloud and AI reside on," per the job posting.
- The company is looking to generate energy with nuclear fission, which is when an atom splits and releases energy as a result of that splitting.

Amazon just bought a 100% nuclear-powered data center

Michelle Lewis | Mar 5 2024 - 8:06 am PT | 51 Comments

Photo: Talen Energy

Amazon, Google and Microsoft signal growing interest in nuclear, geothermal power

Rising demand from artificial intelligence is forcing big technology companies to look beyond wind and solar for clean energy.

By **Heather Clancy** March 25, 2024

An illustration of a data center at a Talen Energy site in Pennsylvania. Credit: Talen Energy

Heather Clancy

VP, Editor at Large

GreenBiz Group

@GreenTechLady

Appearance of SMRs

< Difficulty in New Build >

- Loss of construction capability, Collapse of supply chain
- Privatization (Short term project, Operation rather than construction)
- Construction competitiveness (Labor, Construction regulation, Welfare, Localized supply, etc.)

☞ Modularization (Construction↓ Heavy industry↑)

< Safety concerns >

- Safety related cost increase (ESF)
- Public acceptance

☞ Small

< Nuclear use expansion >

- Replacement of fossil fuels, Hydrogen generations, etc.
- Flexible operation

Applications of SMRs

Coal replacement

Heat & Steam supply

Desalination

Hydrogen generation

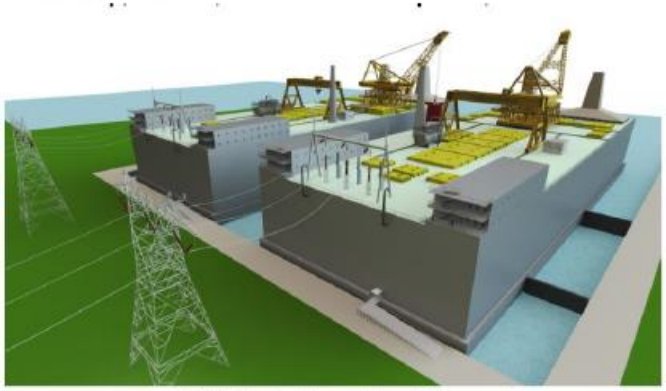
Mine application

Islands & Outback

SMR at Sea

〈KLT-40s〉 러시아

〈ACPR〉 중국



〈THORCON〉 미국+한국

〈BANDI〉 한국

SMR for Propulsion

- Nuclear propulsion : 40 Knots
- Logistics speed →→oubled
- No refueling
- No canal

- Existing Container ship
  - Design speed: 30 Knots
  - Operating speed : 15 Knots

  (Fuel and CO_2 reduction)

Changes due to SMRs

- Heavy industry volume of NuScale (77MWe)
  - ~ 1/3 of APR1400 (Heavy industry ↑) (Construction ↓)

☞ Market leadership moves from construction to heavy industry!

- Module production
  - Same, Massive production

☞ Custom product → Ready-made (Off the shelf items) (100%operation)

  - Module should meet the regulations of ALL NATIONS.

☞ Regulatory leadership dominates.

- Heavy industry prefers SMRs to large NPPs

☞ Power moves from utility to heavy industry.

- Expanded deployment of SMRs

☞ Paradigm shift (Larger → Small)

☞ Still Large NPP is better → Solution?

SMR Foundry

- SMR Forecast
  - NuScale, X-energy, BWRX-300 etc. lead the SMR market.
  - i-SMR, SMART Uncertain
- Nuclear Regulatory Leadership of Korea
  - Skeptical

☞ SMART, SFR experience

- Remaining

☞ Competitive heavy industry

☞ Foundry :

- Manufacture without own design (TSMC)

☞ Design capability

SMR Development

- Traditional NPP Development
  - Conceptual design → Basic design → Detailed design
  - Experimental reactor → Prototype reactor → Demonstration reactor
  - Utility + Licensing

  ☞ Keeping the national infrastructure and manpower!
- SMR Development
  - ~ Basic design →Licensing, Establishment of Corporation, Investment
  - Design finish along the licensing processes
  - FOAKE (First Of A Kind Engineering)

  ☞ Developing!
- Development Paradigm Shift

  ☞ Investment at the early stage of research

  ☞ Premise for the investment → Foundry

New Trends due to SMRs

- Leadership: Government → Private
- Importance: Development → Investment
  - Investor management → promotion and public relation
- Research: Infrastructure → Development
  - Heavy industry, Secure investment
- Market: Domestic → International
  - International recognition → promotion and public relation (international)
- Regulation: Domestic → International leadership
- Current situation: Spring and Autumn Warring State (春秋戰國)
  - Investors → SMR Investment Company → Management capability
  - COP → Government supports

☞ All the issue tackling → Leadership!

Future Shapes of Korean Nuclear

- Domestic
  - Climate change and Carbon neutral activities
  - Enhancement of energy security
  - Sustainable economic development

  ☞ Nuclear portion increase (both electricity and hydrogen)

- International
  - Carbon free energy source
  - Replacements of the existing NPPs
  - Expansion of nuclear applications
  - Proper worldwide energy mix
  - Sustainable economic development

  ☞ Nuclear exports, SMR development

Missions

- Energy mix & Climate change
  - ☞ Nuclear involvements to the Energy planning (Load duration & Screening)
- Tackling Green-Washing
  - ☞ Active PA
  - ☞ RE100 → CF100
- Technical innovations
  - ☞ SMR's, Nuclear Hydrogen, ATF etc.
- High level wastes
  - ☞ Solve! (not Talk)
- International collaboration
  - ☞ Nuclear phase-out policy, PA activities
  - ☞ Common good