2025 제2차 삼척시 탄소중립 콜로키움

기후위기 시대의 AI
새로운 기후 해법인가? 리스크인가?

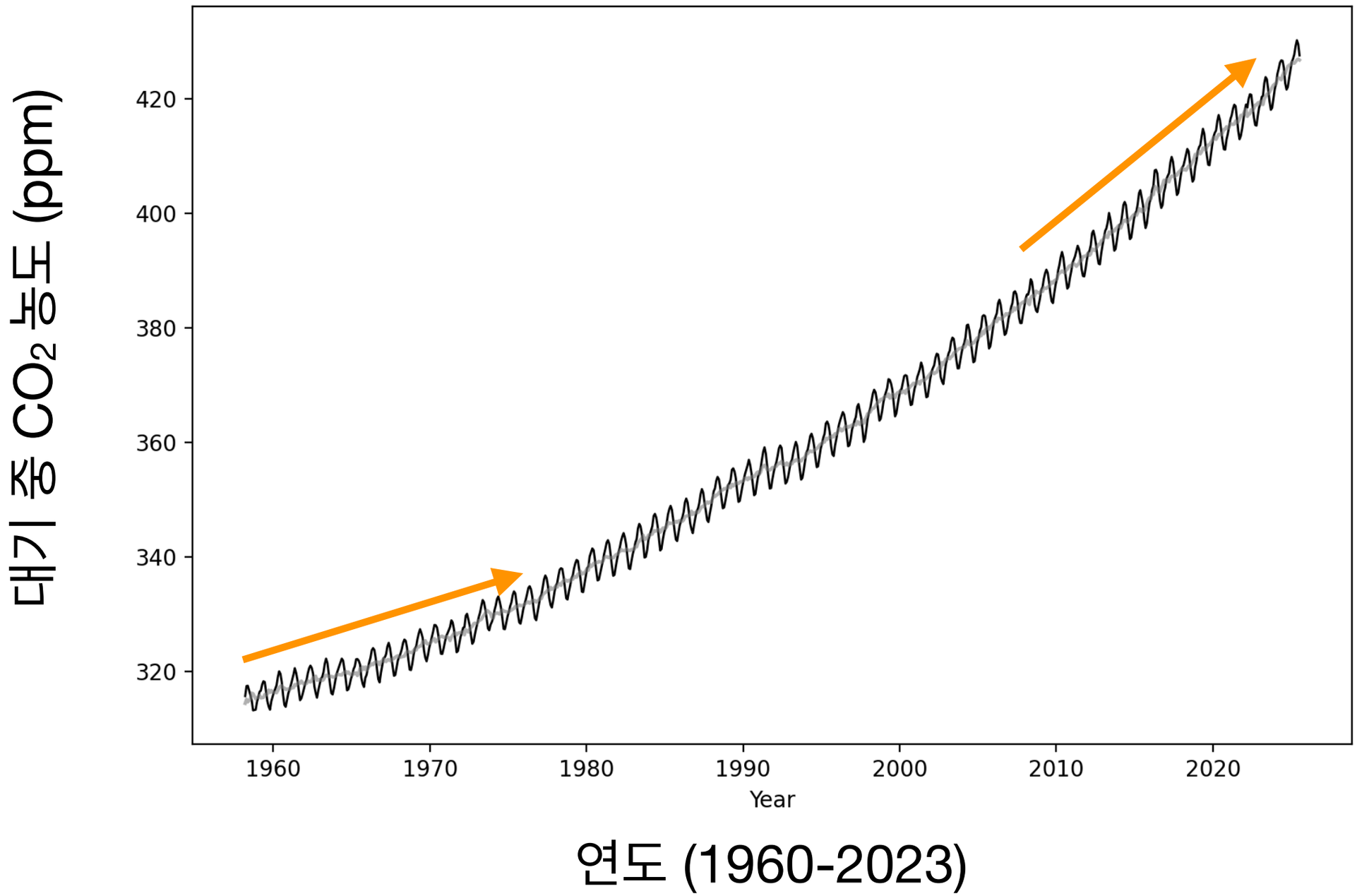
강원대학교 전자AI시스템공학과
오승민

Oct 27, 2025

환경부 Ministry of Environment
삼척시 SAMCHEOK CITY
SCNC 삼척시탄소중립지원센터 Samcheok-si Carbon Neutrality Support Center
SAMPYO Cement
시멘트산업사회공헌재단 Cement Industry Social Contribution Foundation

기후변화와 탄소중립

지구 온난화의 주범, 이산화탄소



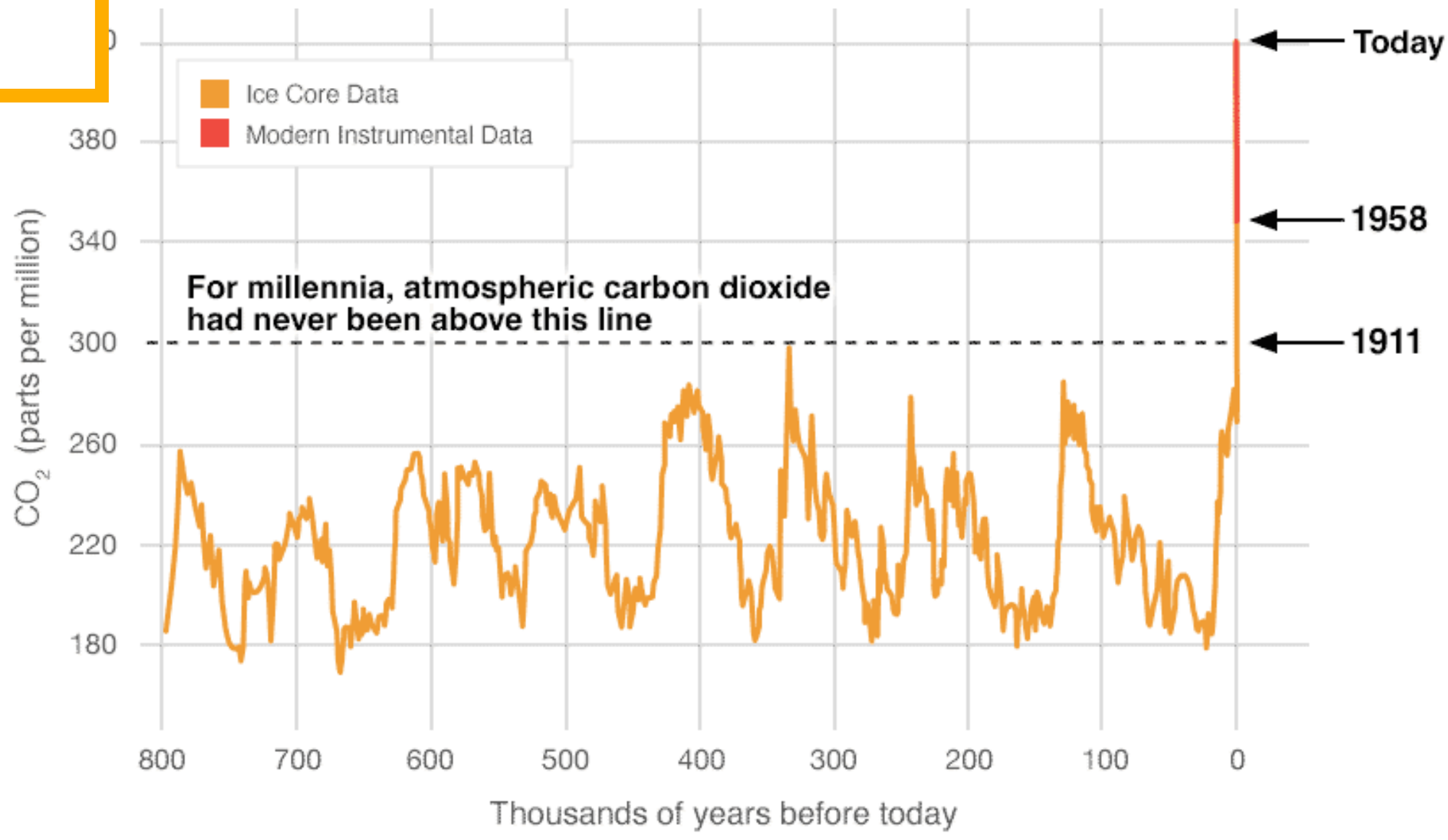
Source: Mauna Loa CO_2 record (NOAA / Scripps)

지구 온난화의 주범, 이산화탄소

Carbon Dioxide

LATEST MEASUREMENT: August 2025

425 ppm



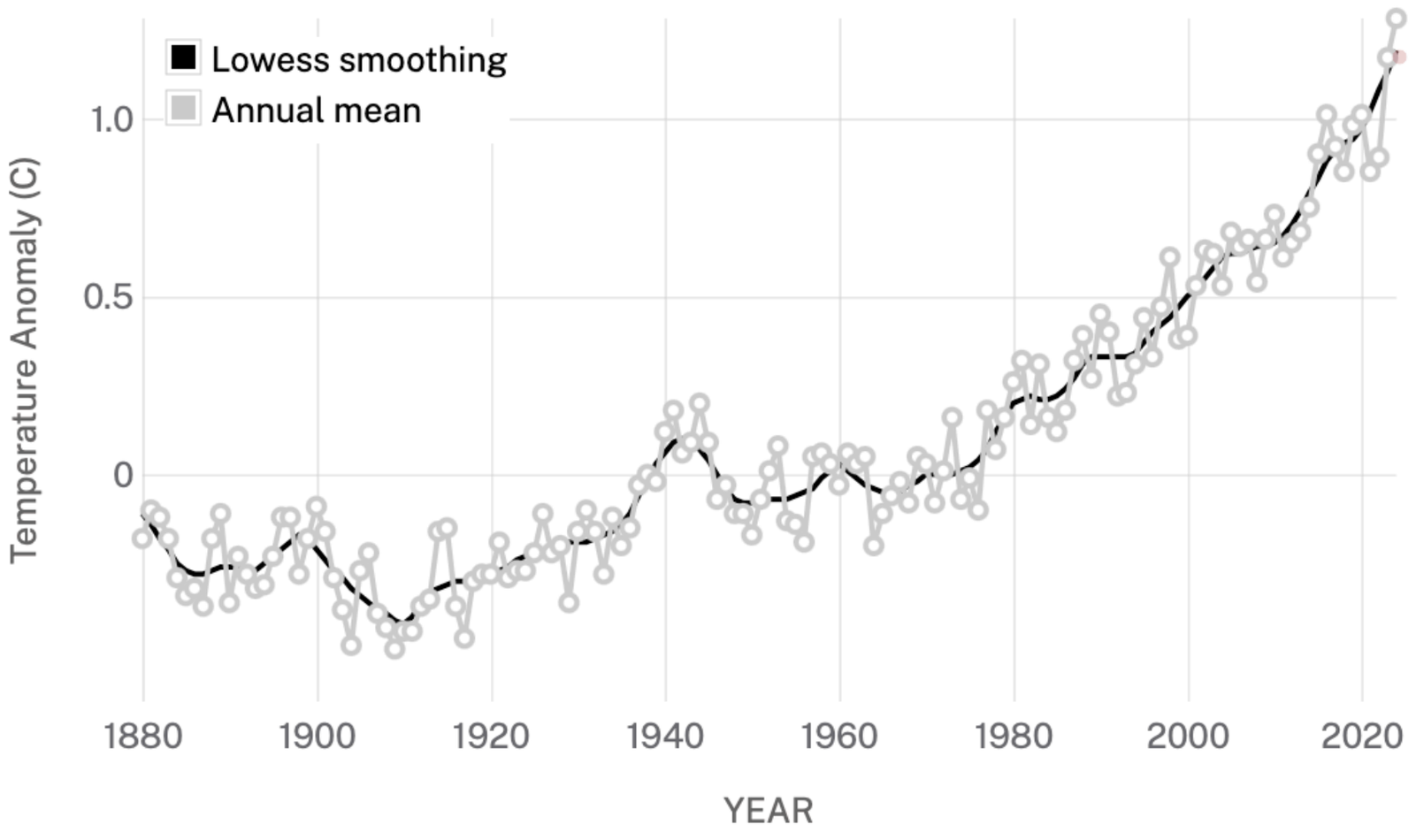
Source: NASA Climate Change, https://climate.nasa.gov/vital-signs/carbon-dioxide/

지구 온난화의 주범, 이산화탄소

Global Temperature

LATEST ANNUAL AVERAGE ANOMALY: 2024 *i*

1.28 °C



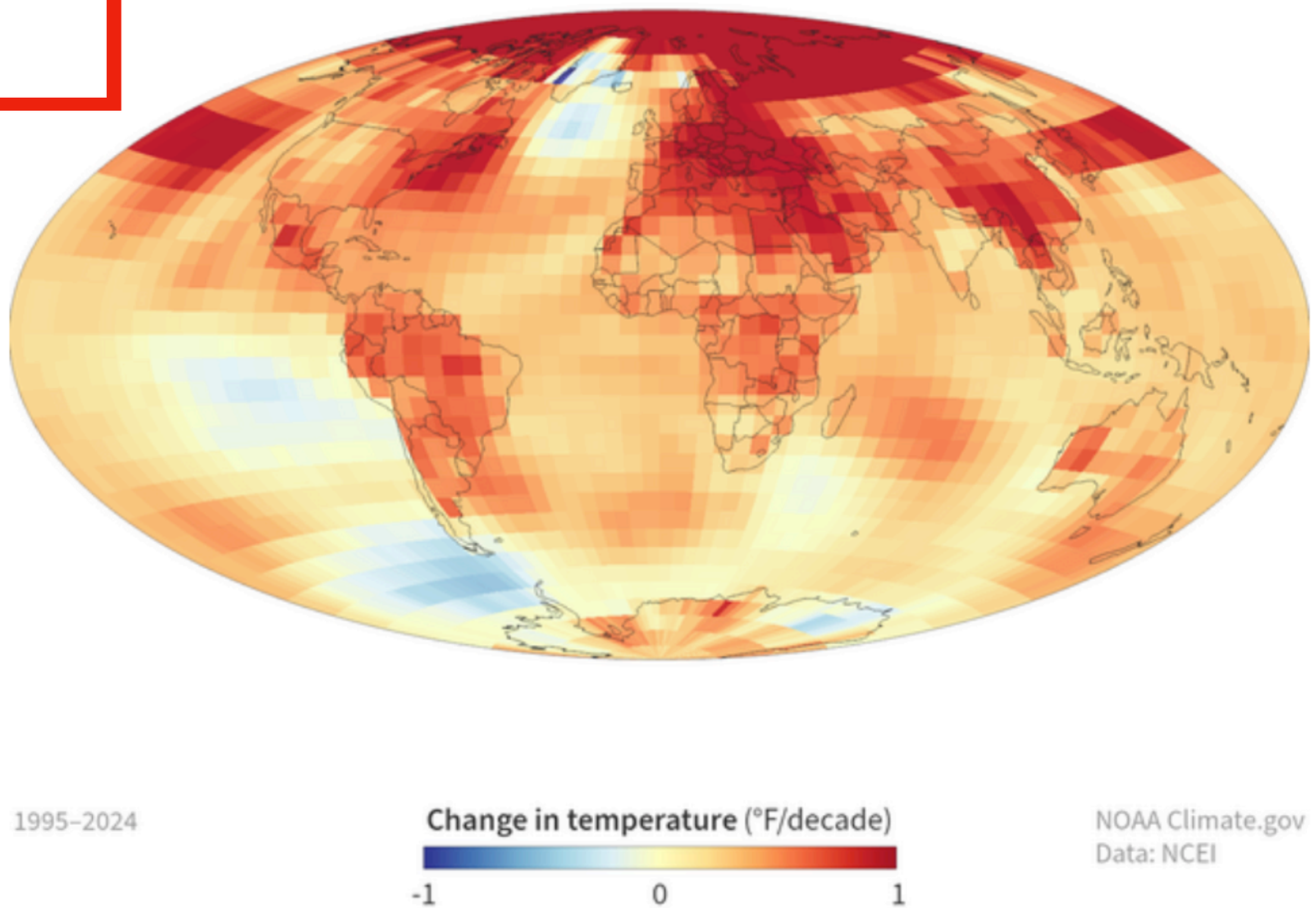
Source: NASA Climate Change, https://climate.nasa.gov/vital-signs//global-temperature/

지구 온난화의 주범, 이산화탄소

Global Temperature

LATEST ANNUAL AVERAGE ANOMALY: 2024 *i*

1.28 °C

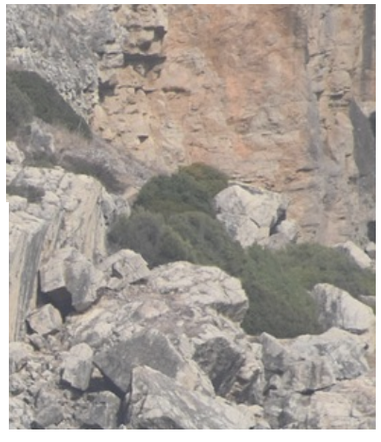


Source: NASA Climate Change, https://climate.nasa.gov/vital-signs//global-temperature/

기후변화와 기후재해

사회

[현장IN] 최악의 '폭염 테러'...2016 뜨거웠던 여름의 흔적



입력

2018년 폭염 '역대 최고'…최고기온 60% 갈아치웠다

2018-08-06 11:30

2024년, 1973년 이래 가장 더워…평균기온·열대야일수' 역대 1위



사회

서울 전역 올해 첫 폭염주의보...4년 연속 '6월 열대야' 관측

'폭염' 강원, 횡성 최고체감온도 35도 예상…강릉 8일째 열대야

2025-08-21 11:17

Source: Pixabay - ian1550, https://pixabay.com/users/ian1550-19107449/

기후변화와 기후재해



Source: NASA Climate Change; Mike McMillan/USFS; Tomas Castelazo/Wikimedia Commons (CC BY-SA 4.0); NASA

기후위기, 모두가 체감하는 현실

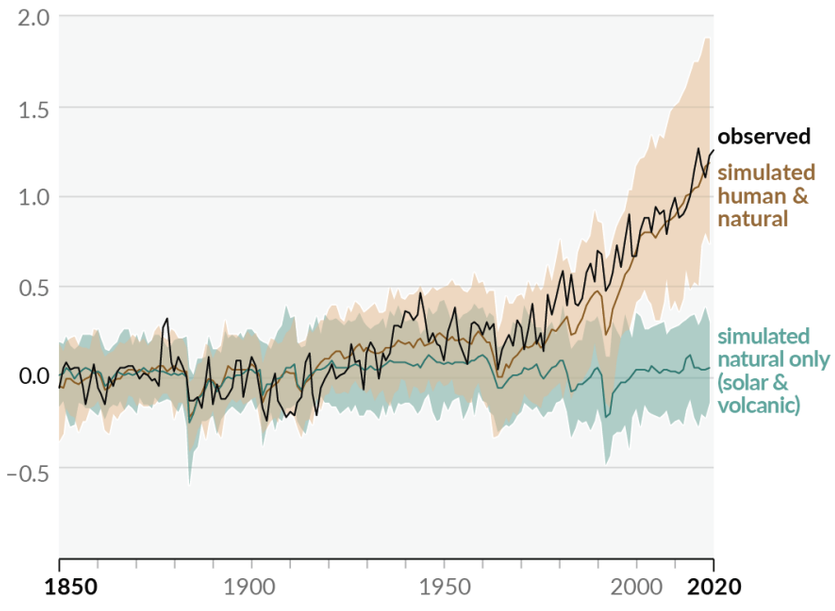
인간이 기후변화 원인임을
뒷받침하는 증거의 강화

+

기후재해 체감으로 인한
기후 대응 공감대 확산

IPCC Sixth Assessment Report

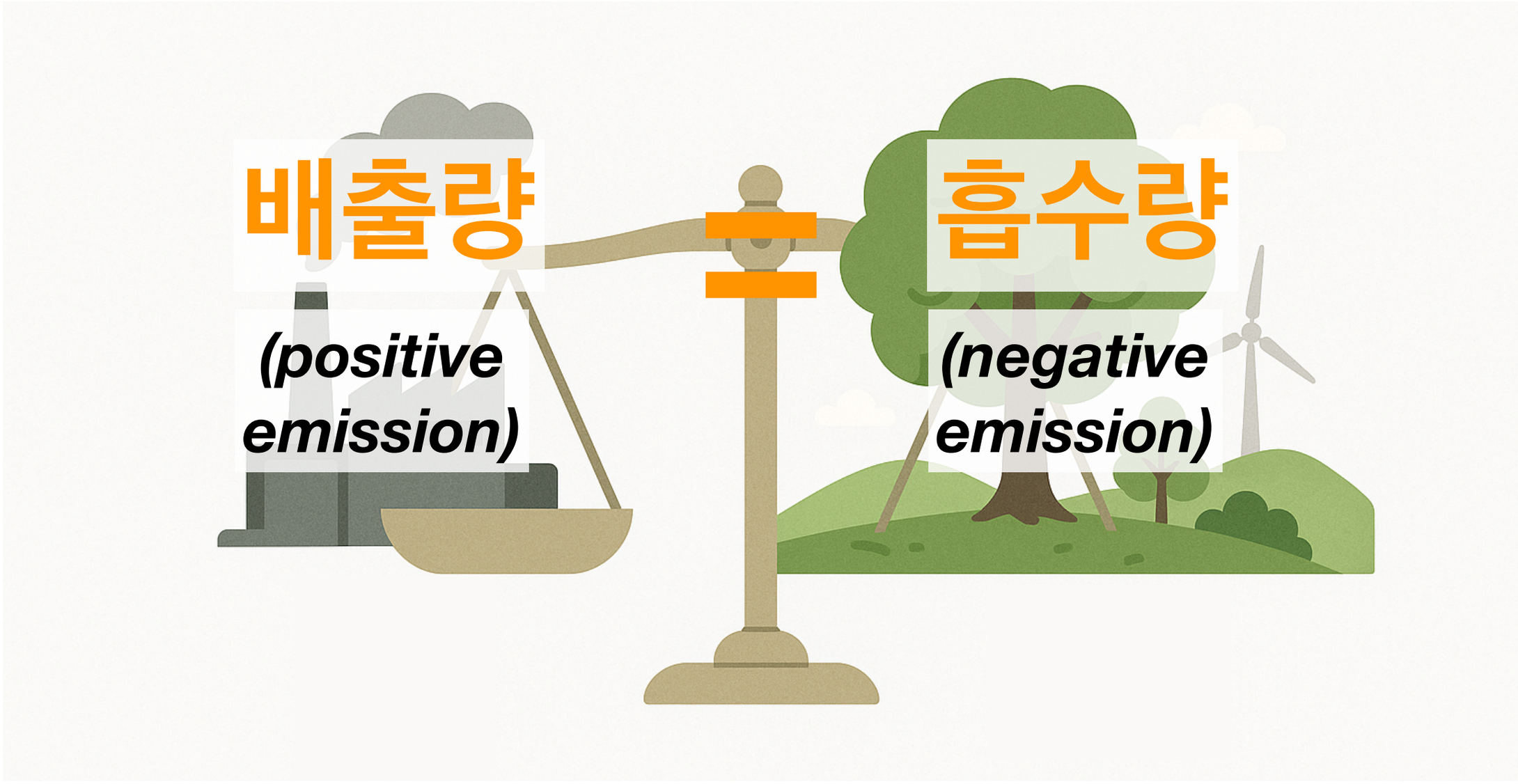
A.1 It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.





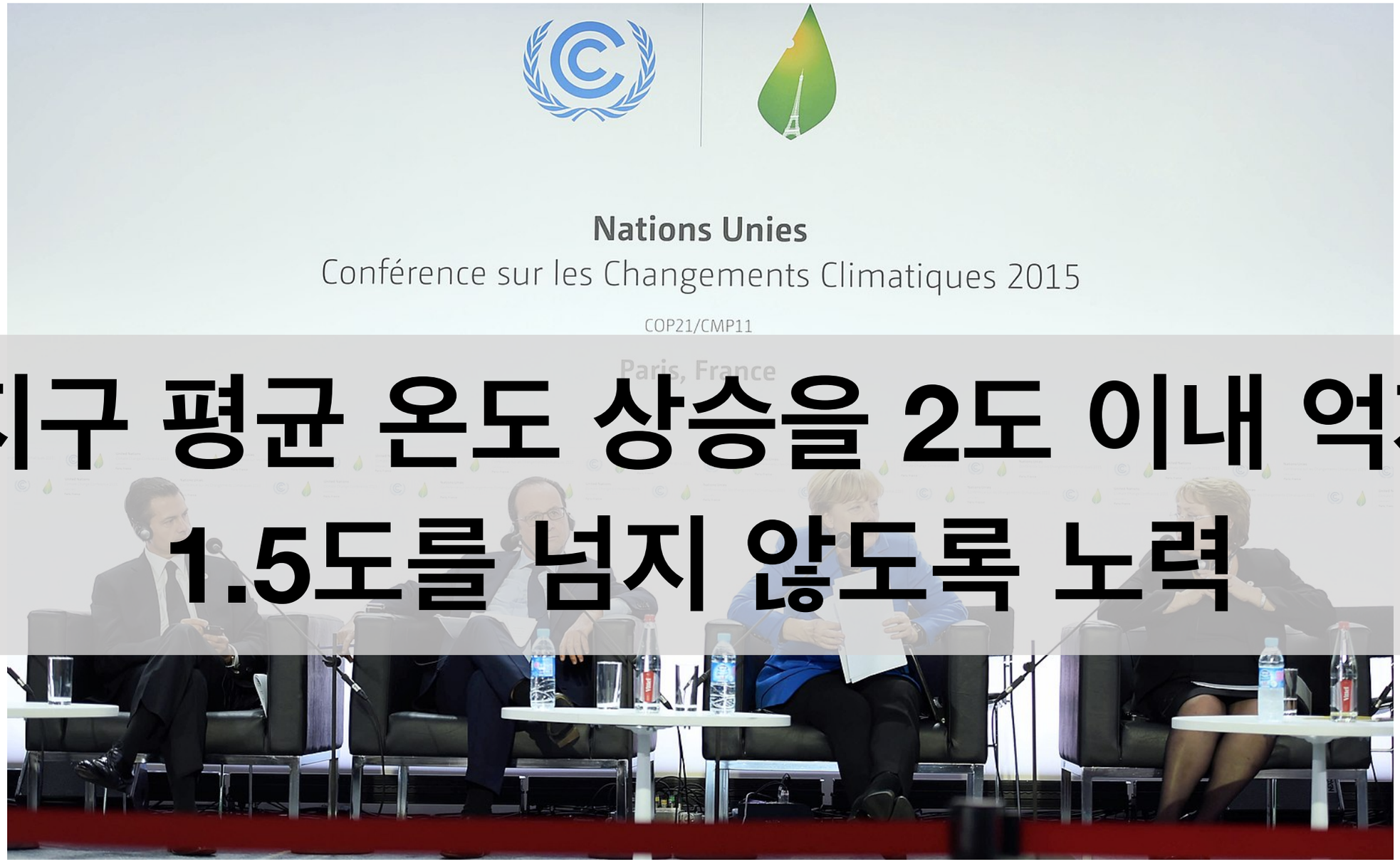
Source: IPCC 6th SAR (left), Pixabay - niekverlaan https://pixabay.com/users/niekverlaan-80788/ (right)

탄소중립



Source: Created by user using ChatGPT (DALL·E)

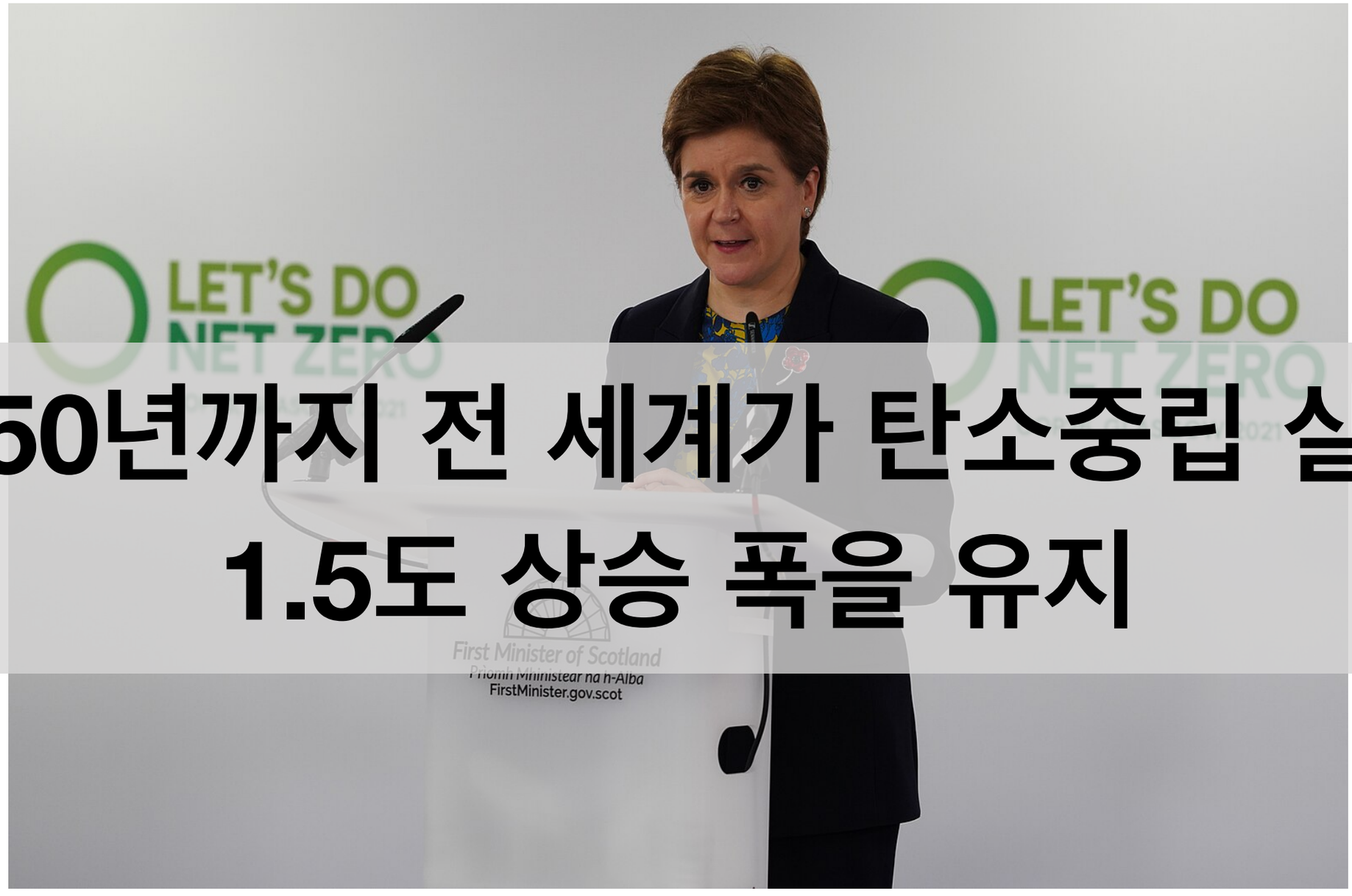
파리협정 (2015)



지구 평균 온도 상승을 2도 이내 억제
1.5도를 넘지 않도록 노력

Source: Presidencia de la República Mexicana, CC BY 2.0, via Wikimedia Commons

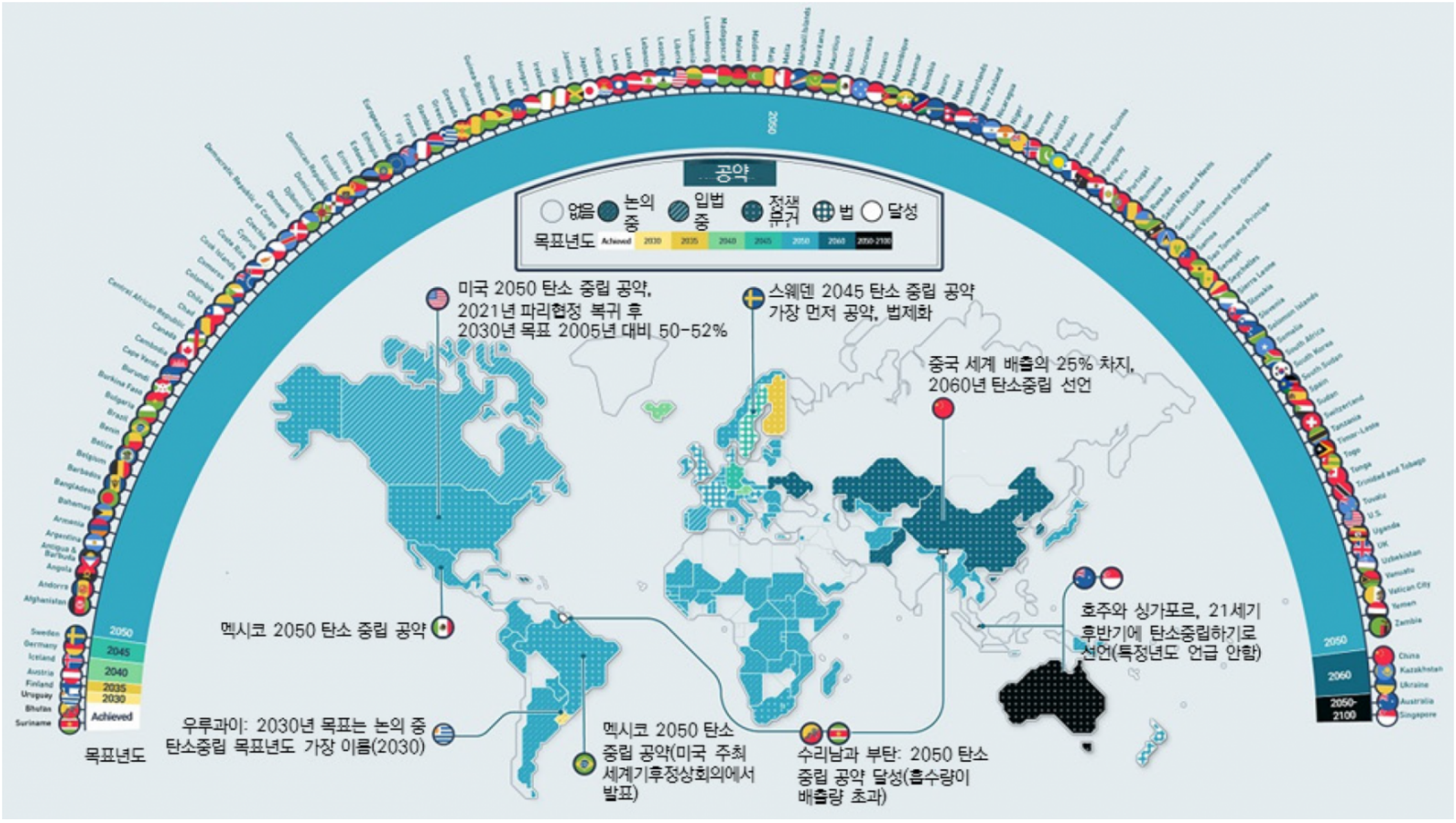
글래스고 기후 합의 (2021)



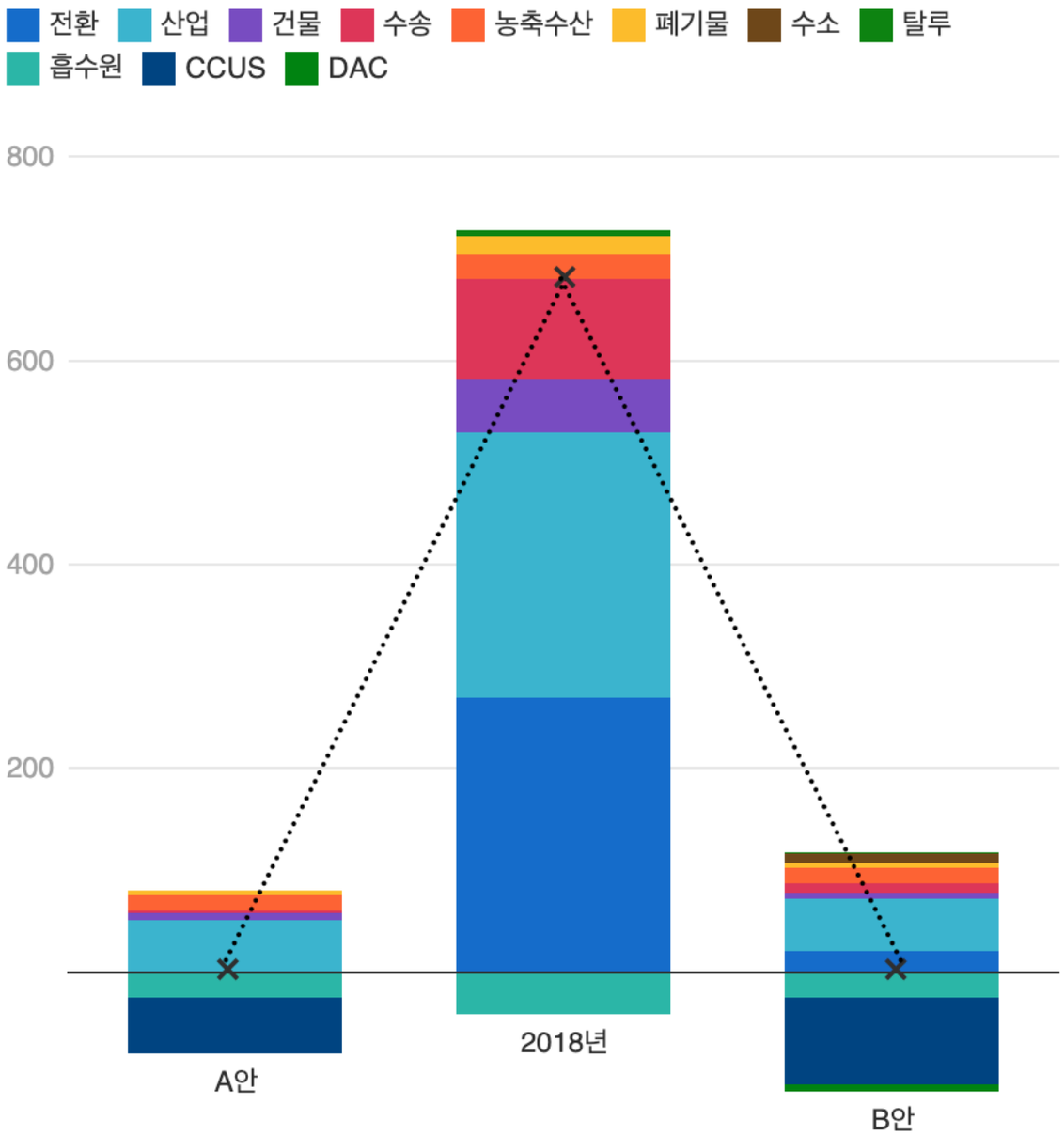
2050년까지 전 세계가 탄소중립 실현,
1.5도 상승 폭을 유지

Source: Scottish Government, CC BY 2.0, via Wikimedia Commons

전지구 탄소중립 공약


공약
없음
논의 중
입법 중
정책 유지
법
달성
목표년도
Achieved
2030
2035
2040
2045
2050
2060
2050-2100
미국 2050 탄소 중립 공약,
2021년 파리협정 복귀 후
2030년 목표 2005년 대비 50-52%
스웨덴 2045 탄소 중립 공약
가장 먼저 공약, 법제화
중국 세계 배출의 25% 차지,
2060년 탄소중립 선언
멕시코 2050 탄소 중립 공약
호주와 싱가포르, 21세기
후반기에 탄소중립하기로
선언(특정년도 언급 안함)
우루과이: 2030년 목표는 논의 중
탄소중립 목표년도 가장 이름(2030)
멕시코 2050 탄소
중립 공약(미국 주최
세계기후정상회의에서
발표)
수리남과 부탄: 2050 탄소
중립 공약 달성(흡수량이
배출량 초과)
목표년도
2050
2045
2040
2035
2030
Achieved

국내 탄소중립 시나리오



종합

국내 순배출량을 0으로 하는 2개 시나리오로 구성

IPCC 1.5°C 특별보고서('18)를 토대로 모든 국가가 2050년 탄소중립을 추진한다는 전제하에 국외 감축분이 없는 2050년을 가정

산업화 이전 대비 지구 평균온도 상승을 1.5도 이내로 억제하기 위해서는 전 지구적으로 2050년 탄소중립 필요성 제시

A안

화력발전 전면 중단 등
배출 자체를 최대한 줄이는 시나리오

B안

화력발전이 잔존하는 대신
CCUS 등 제거기술을 적극 활용하는 시나리오

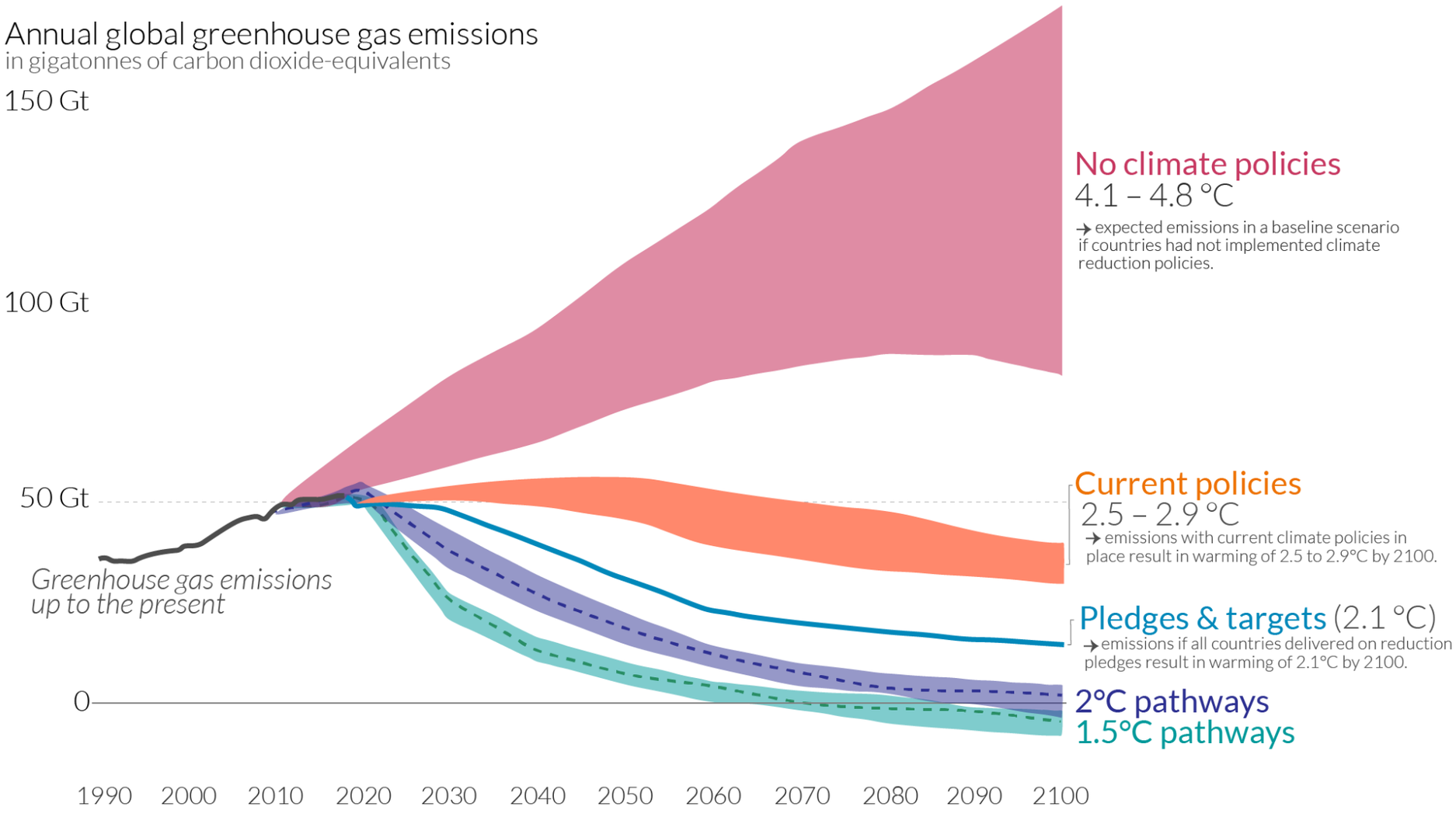
Source: 탄소중립정책포털(https://www.gihoo.or.kr/)

탄소중립, 어디까지 왔을까?

Global greenhouse gas emissions and warming scenarios

– Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
– Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.

Our World in Data

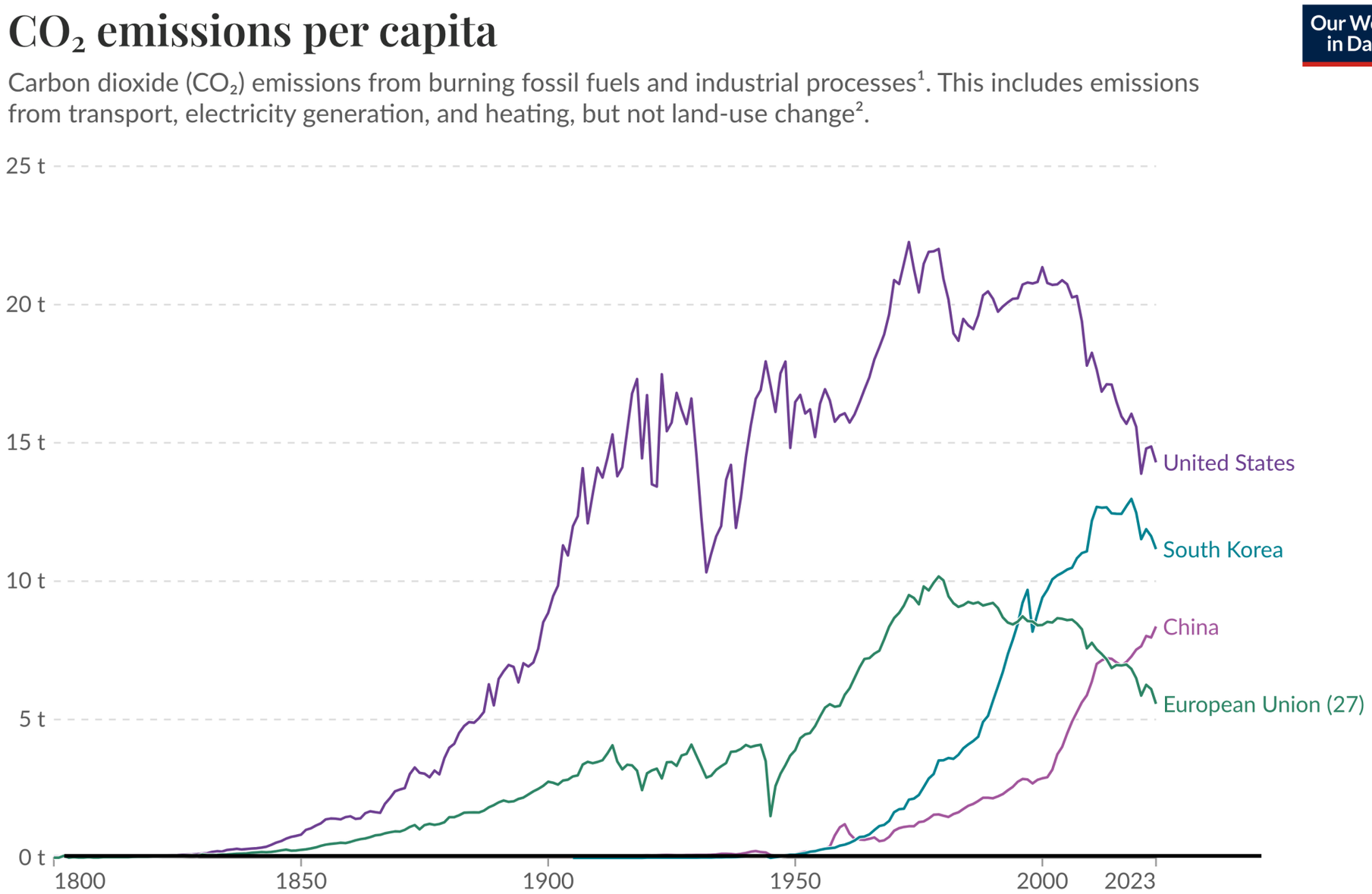


Data source: Climate Action Tracker (based on national policies and pledges as of November 2021).
OurWorldinData.org – Research and data to make progress against the world's largest problems.

Last updated: April 2022.
Licensed under CC-BY by the authors Hannah Ritchie & Max Roser.

Source: Our World in Data (CC BY, Hannah Ritchie & Max Roser)

탄소중립, 어디까지 왔을까?

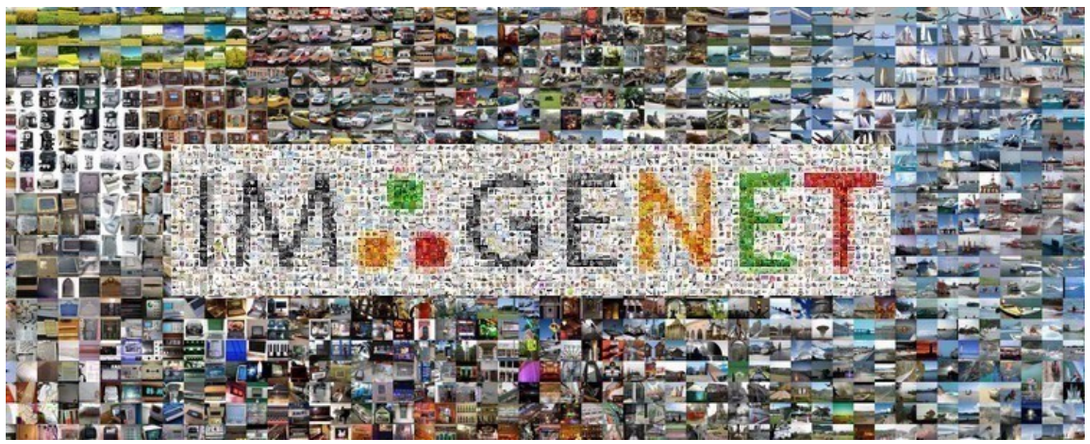


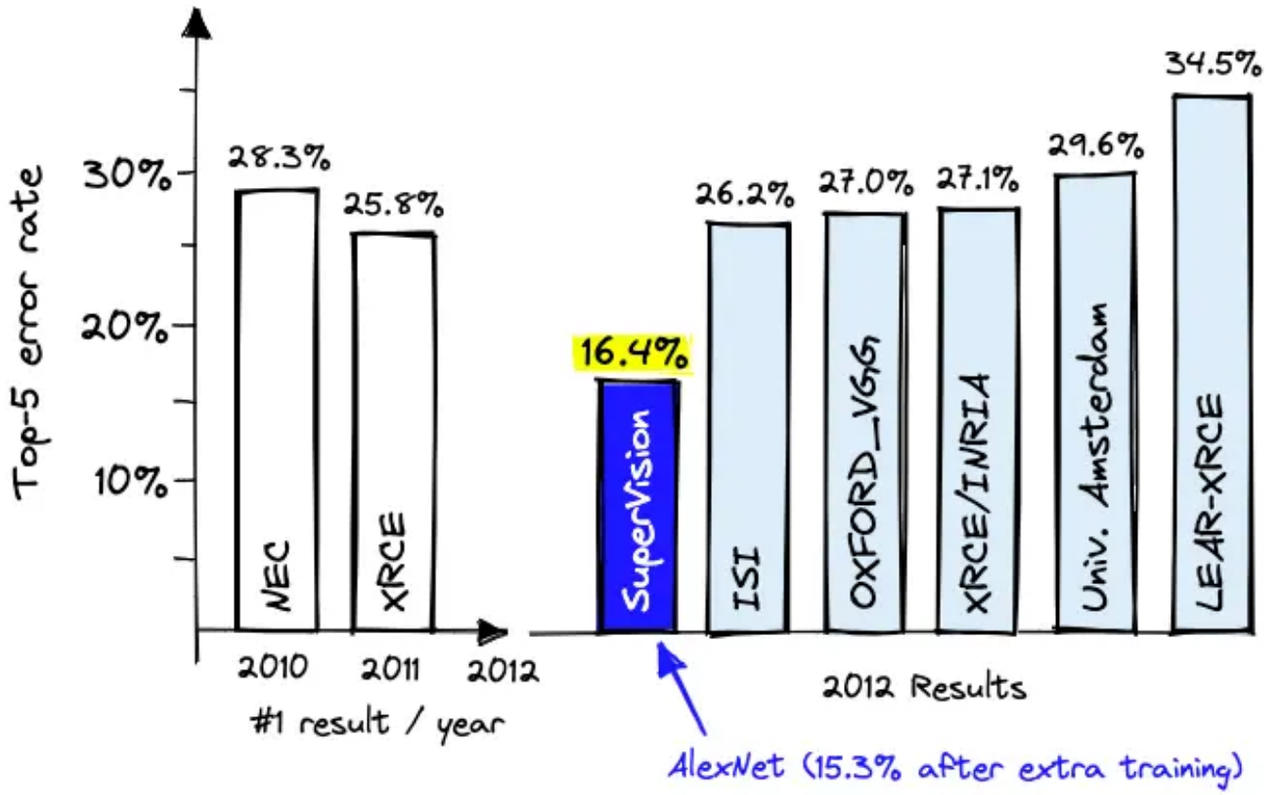
Source: Our World in Data (CC BY); https://ourworldindata.org/co2-emissions

인공지능(AI)

딥러닝의 시작, ALEXNET



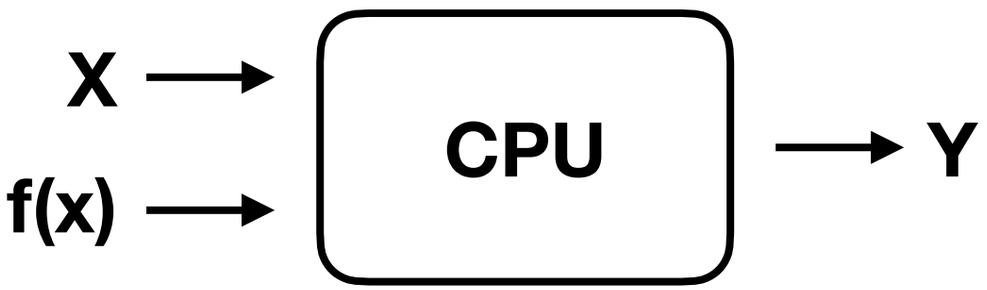




Source: AlexNet and ImageNet: The Birth of Deep Learning, https://www.pinecone.io/learn/series/image-search/imagenet/

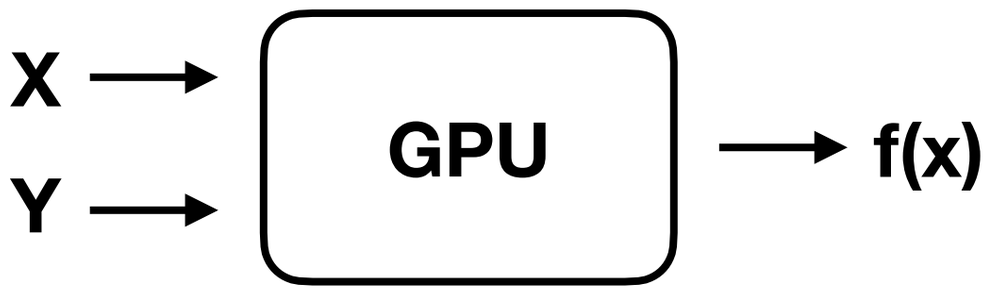
딥러닝의 시작, ALEXNET

Software 1.0



Human Coding

Software 2.0

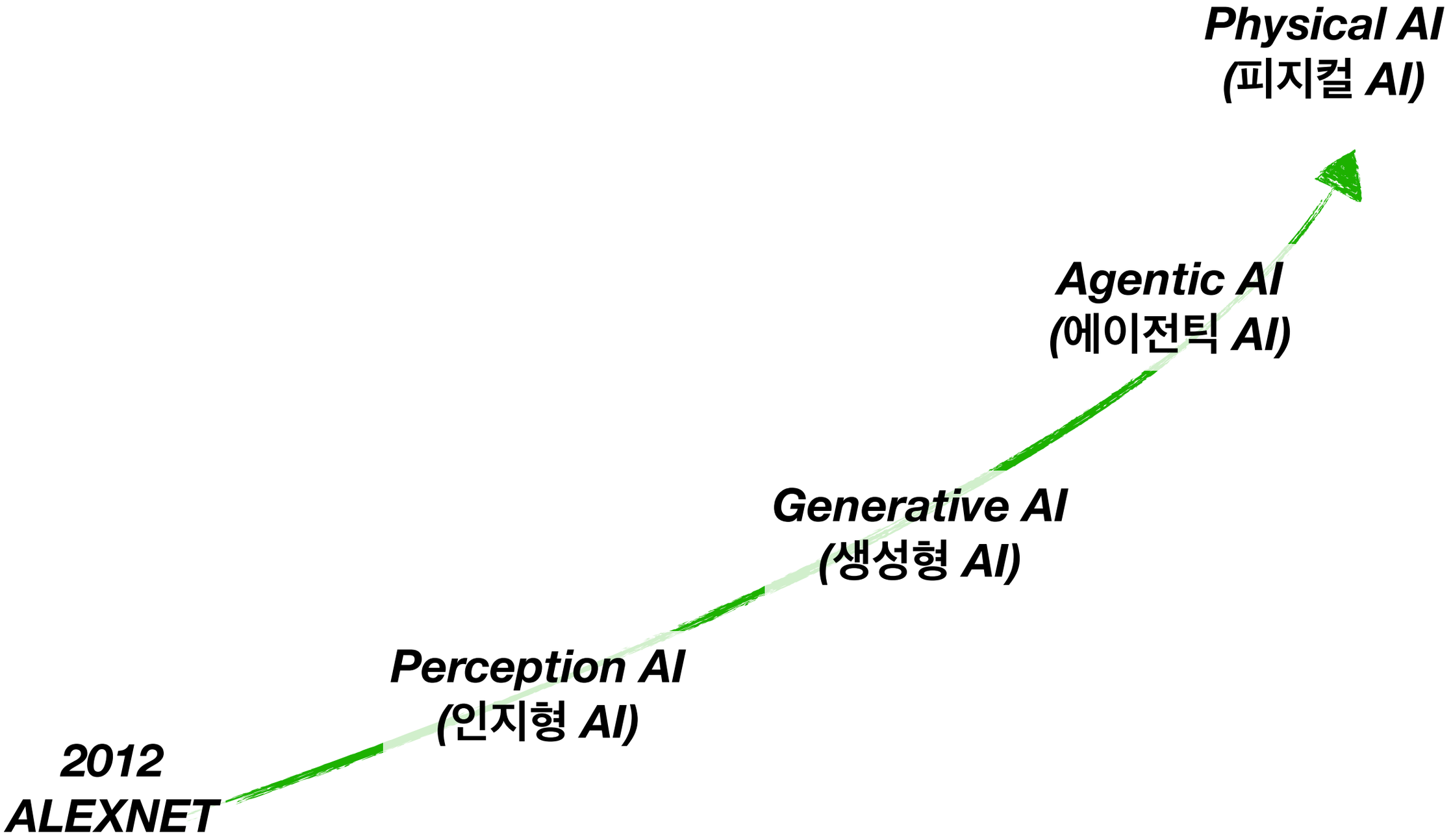


Machine Learning
Deep Learning

Source: Adapted from Andrej Karpathy, “Software 2.0” (2017)

인공지능의 진화

Evolution of AI



Adapted from Jensen Huang's presentation (NVIDIA GTC)

인공지능의 진화 - 인지형 AI

Perception AI

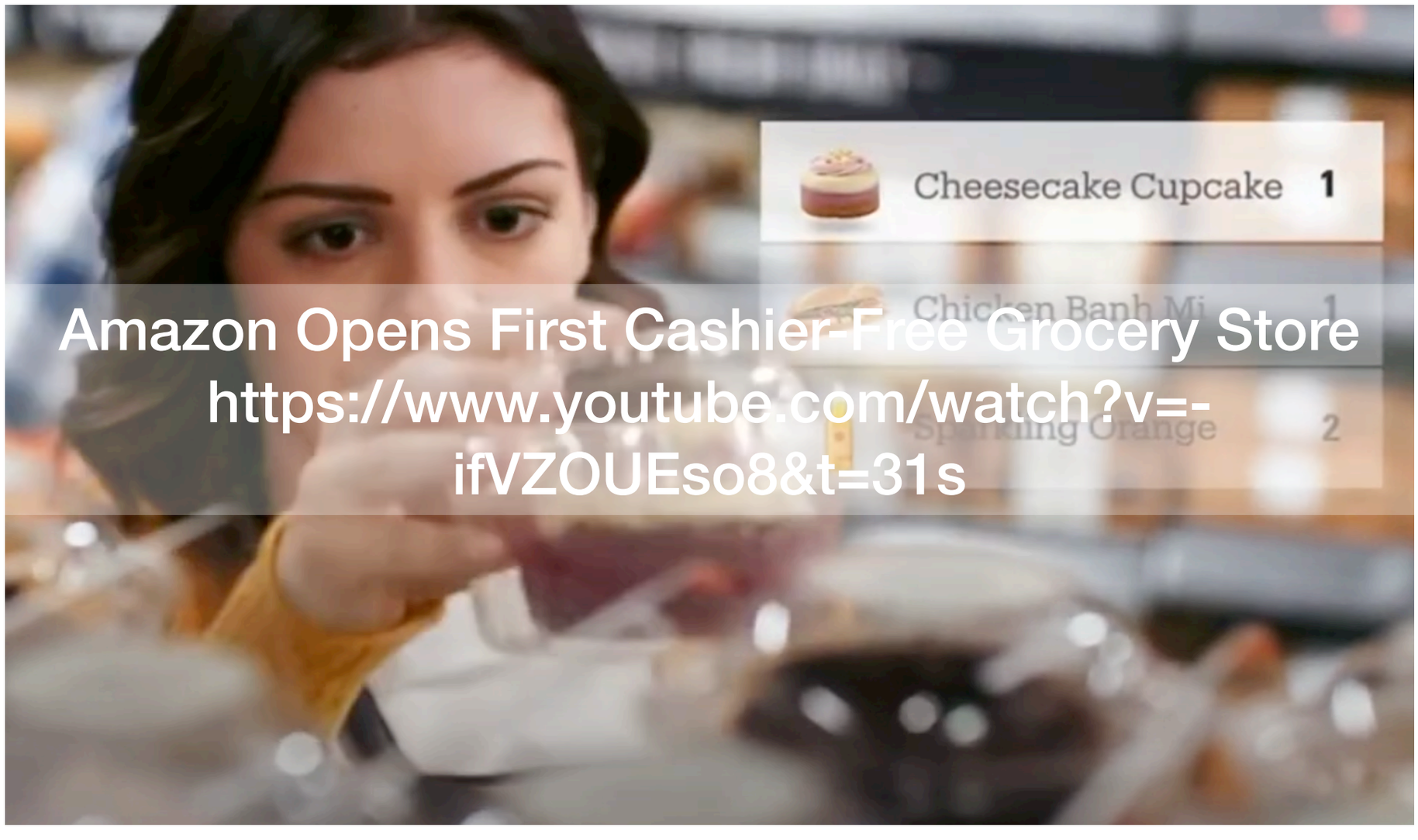
ALEXNET ***Perception AI*** *Generative AI* *Agentic AI* *Physical AI*



인공지능의 진화 - 인지형 AI

Perception AI

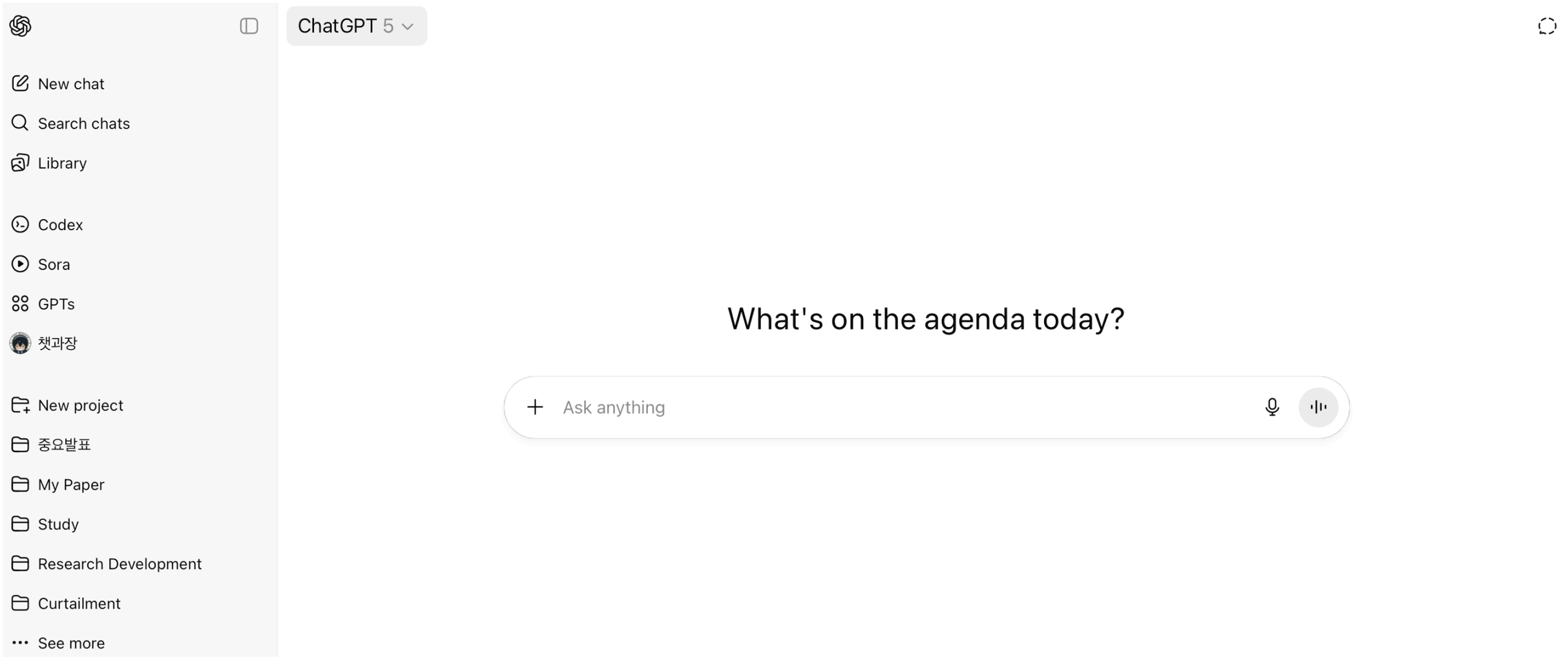
ALEXNET ***Perception AI*** *Generative AI* *Agentic AI* *Physical AI*



인공지능의 진화 - 생성형 AI

Generative AI

ALEXNET *Perception AI* ***Generative AI*** *Agentic AI* *Physical AI*



인공지능의 진화 - 생성형 AI

Generative AI

ALEXNET *Perception AI* ***Generative AI*** *Agentic AI* *Physical AI*

ChatGPT

Gemini

deepseek

perplexity

Claude

Copilot

인공지능의 진화 - 생성형 AI

Generative AI

ALEXNET *Perception AI* ***Generative AI*** *Agentic AI* *Physical AI*





Source: Created by user using ChatGPT (DALL·E)

인공지능의 진화 - 에이전틱 AI

Agentic AI

ALEXNET *Perception AI* *Generative AI* ***Agentic AI*** *Physical AI*

나 다다음주 출장일은 언제지?

Google Calendar과(와) 대화 완료

다다음주(9월 15일 ~ 9월 21일) 일정에서 **출장 관련 이벤트는 없어요.**

혹시 다른 캘린더에도 일정이 있을 수 있는데, 특정 캘린더(예: 회사 캘린더)도 함께 확인해드릴까요?

NOTE: This is an example of Agent Mode, not a fully realized Agentic AI.

인공지능의 진화 - 피지컬 AI

Physical AI

ALEXNET *Perception AI* *Generative AI* *Agentic AI* ***Physical AI***



인공지능의 진화

Evolution of AI

- Training data: Trillions of tokens
- Compute: Thousands of GPUs
- Parameters: Hundreds of billions

Physical AI
(피지컬 AI)

Agentic AI
(에이전틱 AI)

Generative AI
(생성형 AI)

Perception AI
(인지형 AI)

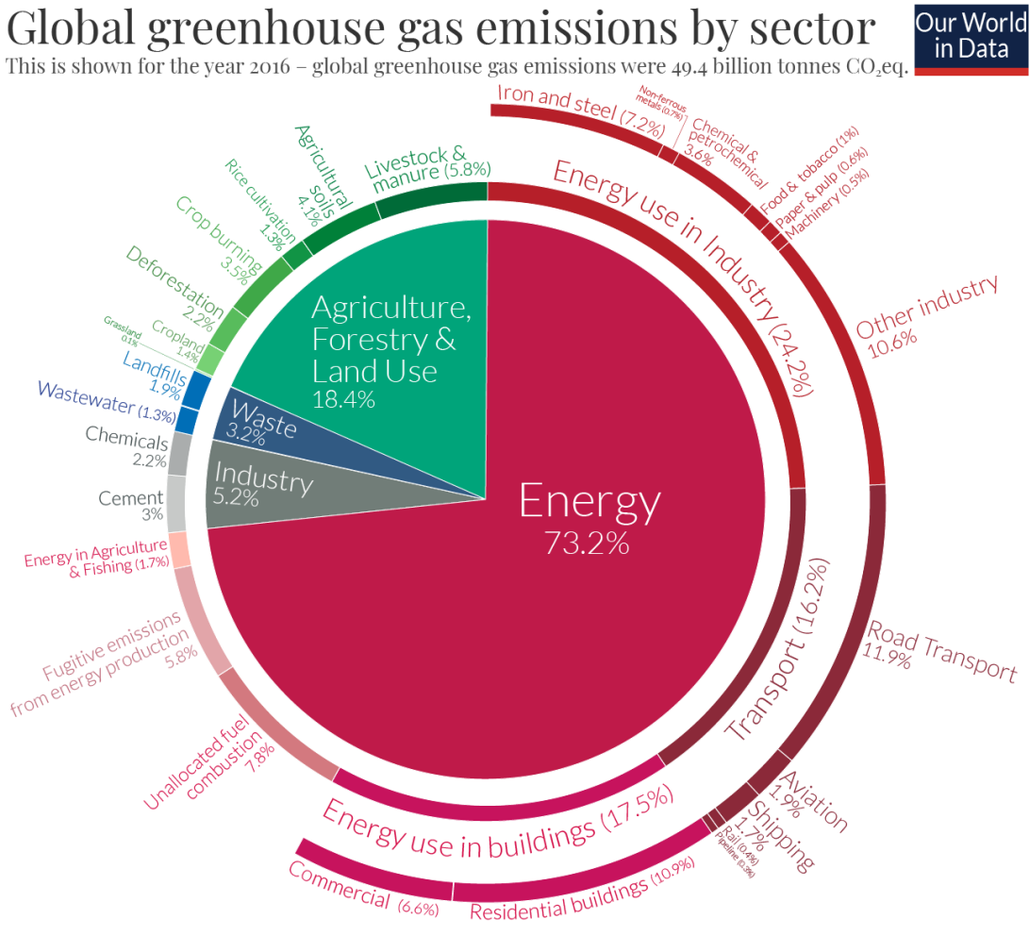
- Training data: ~1.2M labeled images
- 2 GPUs
- Parameters: ~60M

2012
ALEXNET

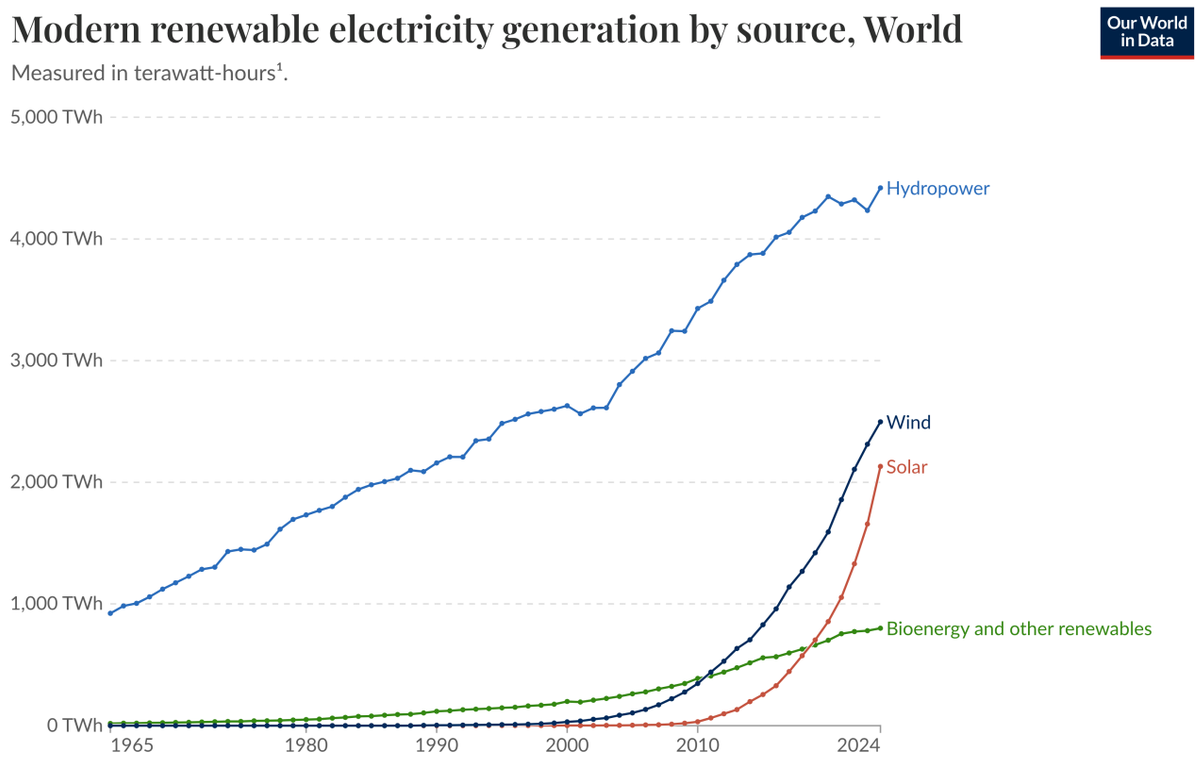
Adapted from Jensen Huang's presentation (NVIDIA GTC)

탄소중립와 인공지능

탄소중립의 핵심 = 에너지 전환



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020). Licensed under CC-BY by the author Hannah Ritchie (2020).

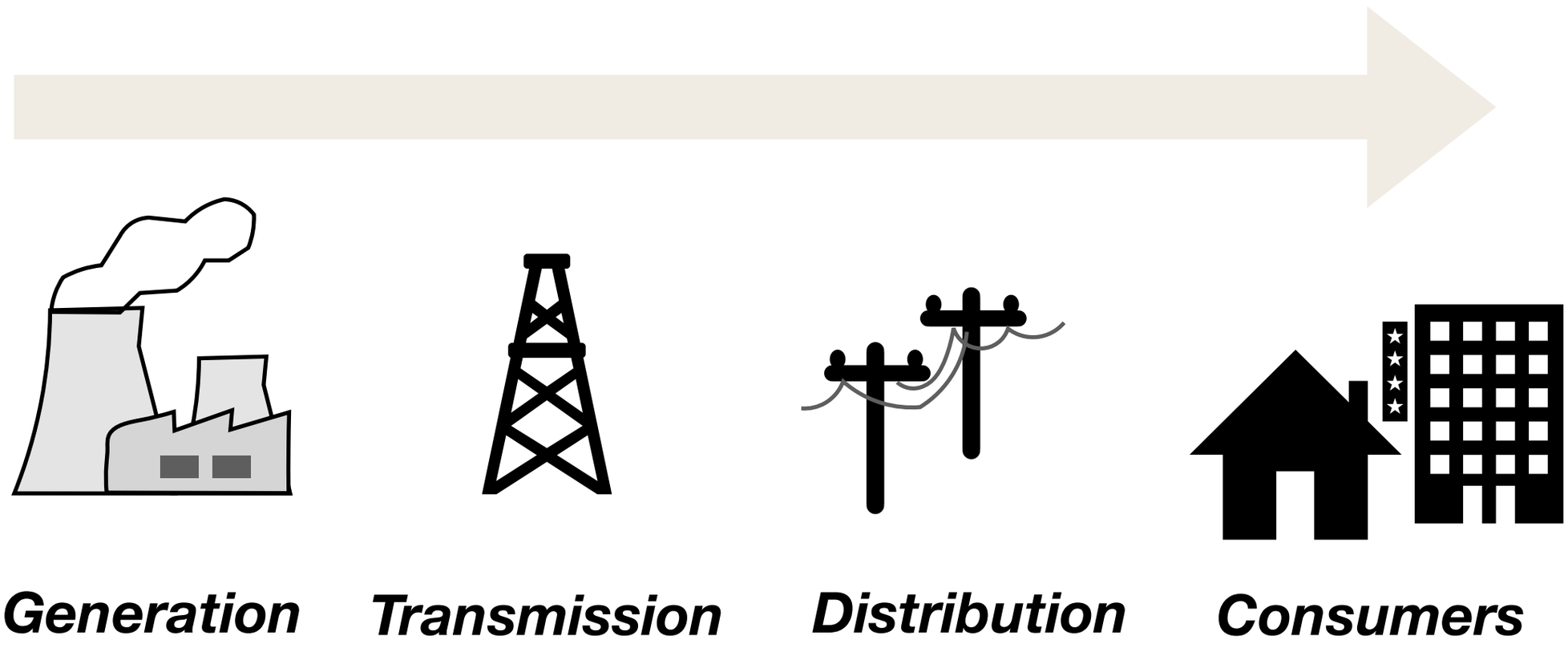


Data source: Ember (2025); Energy Institute - Statistical Review of World Energy (2025) OurWorldinData.org/renewable-energy | CC BY
Note: "Other renewables" include geothermal, wave, and tidal energy.

1. Watt-hour A watt-hour is the energy delivered by one watt of power for one hour. Since one watt is equivalent to one joule per second, a watt-hour is equivalent to 3600 joules of energy.
Metric prefixes are used for multiples of the unit, usually:
- kilowatt-hours (kWh), or a thousand watt-hours.
- Megawatt-hours (MWh), or a million watt-hours.
- Gigawatt-hours (GWh), or a billion watt-hours.
- Terawatt-hours (TWh), or a trillion watt-hours.

Source: Our World in Data (Hannah Ritchie, 2020) (left); Our World in Data, Ember(2025), Energy Institute (right) - CC-BY

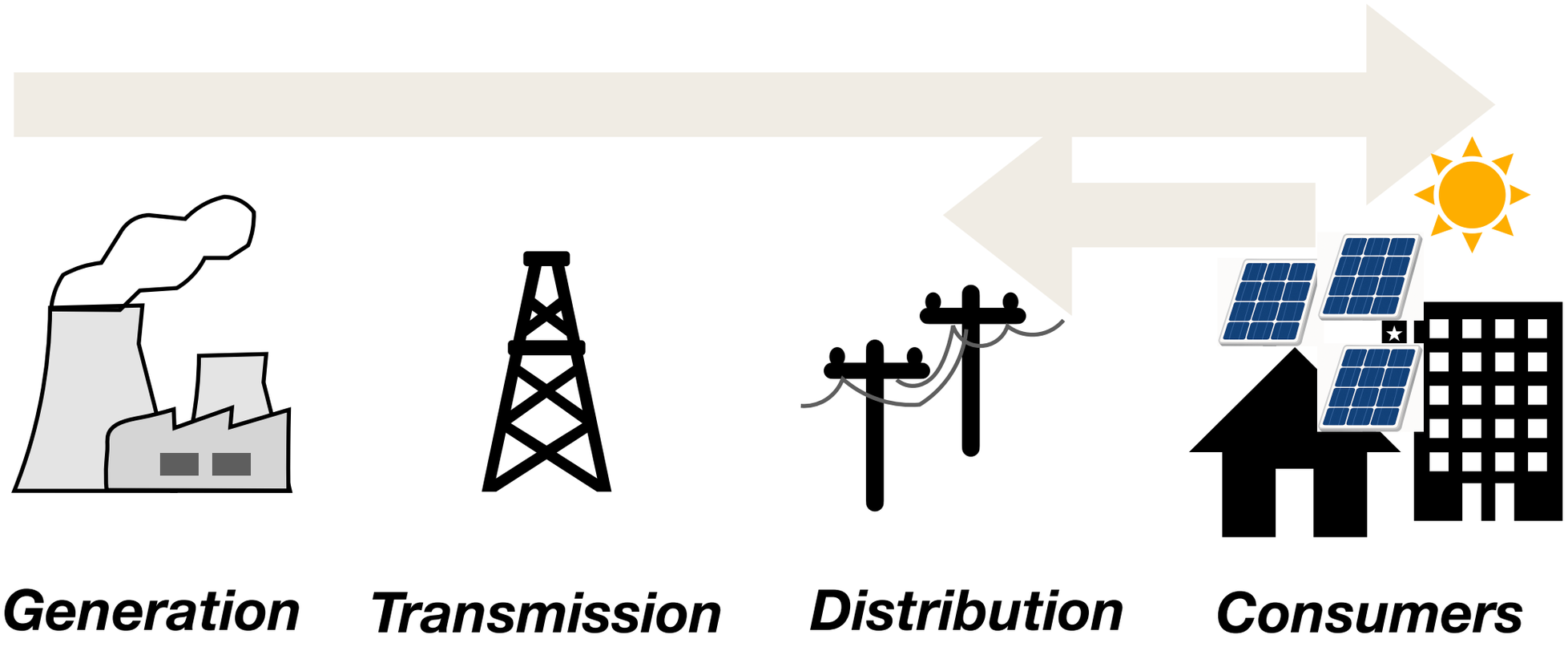
에너지 시스템: 기존 형태



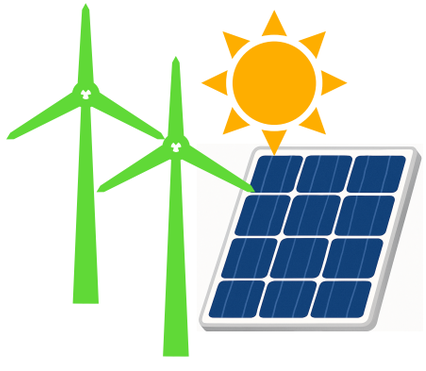
Generation ***Transmission*** ***Distribution*** ***Consumers***

- 한 방향 흐름 (발전소 → 소비자)
- 중앙집중식 발전 (대규모 화력·원자력)
- 디스패처블(조절 가능) 전원 중심
- 공급이 수요에 맞춰짐

에너지 시스템: 현재



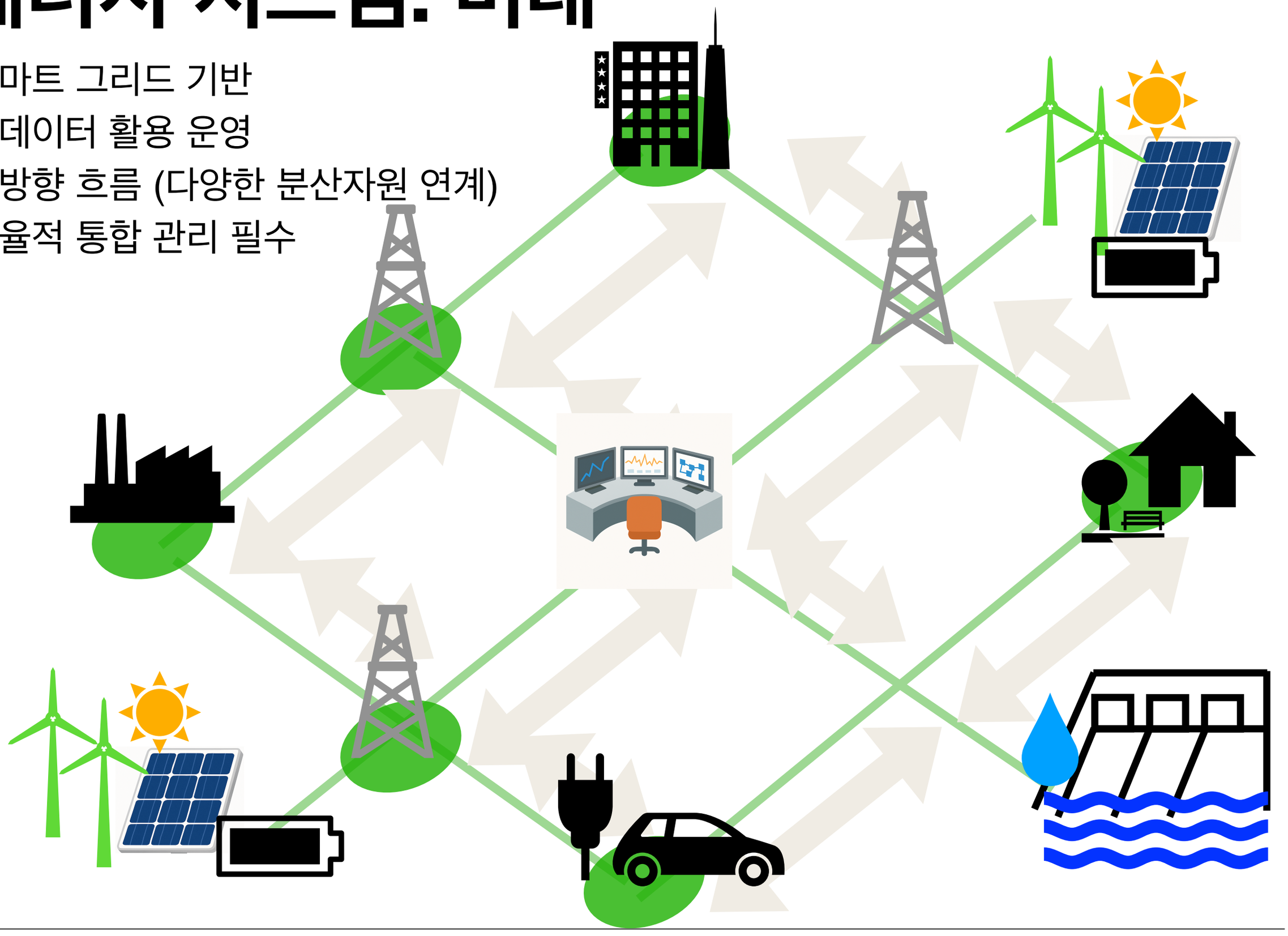
Generation ***Transmission*** ***Distribution*** ***Consumers***



- 신재생 확대 (태양광·풍력 등)
- 디지털화·센서 보급
- 양방향 흐름 (프로슈머 등장)
- 변동성 증가 (공급 ↔ 수요 조정 필요)

에너지 시스템: 미래

- 스마트 그리드 기반
- 빅데이터 활용 운영
- 다방향 흐름 (다양한 분산자원 연계)
- 효율적 통합 관리 필수



AI: 재생에너지 예측·운영 관리

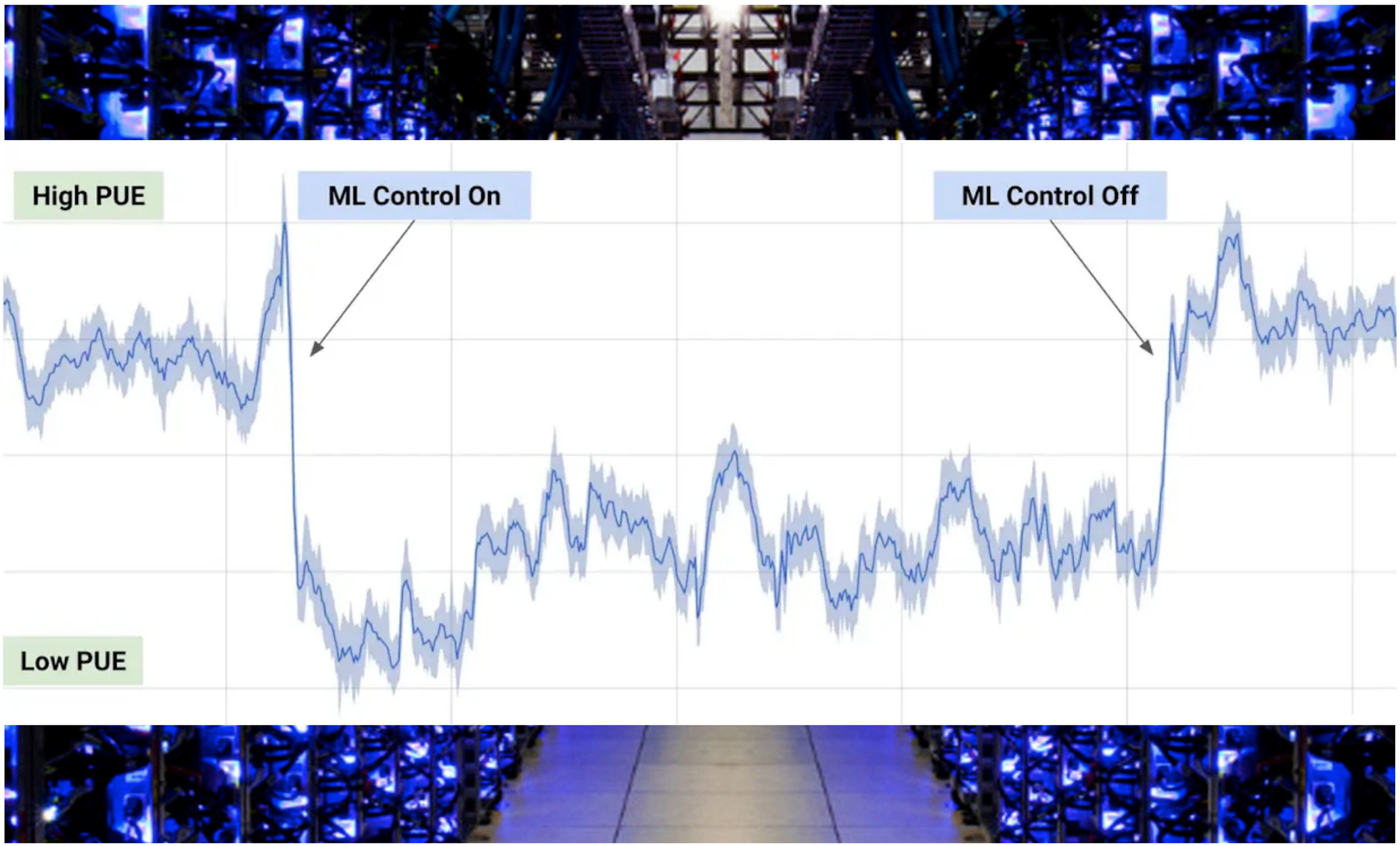
Solar Energy Generation Forecasting



Screenshot from Google Project Sunroof (Google, 2025)

AI: 에너지 효율화

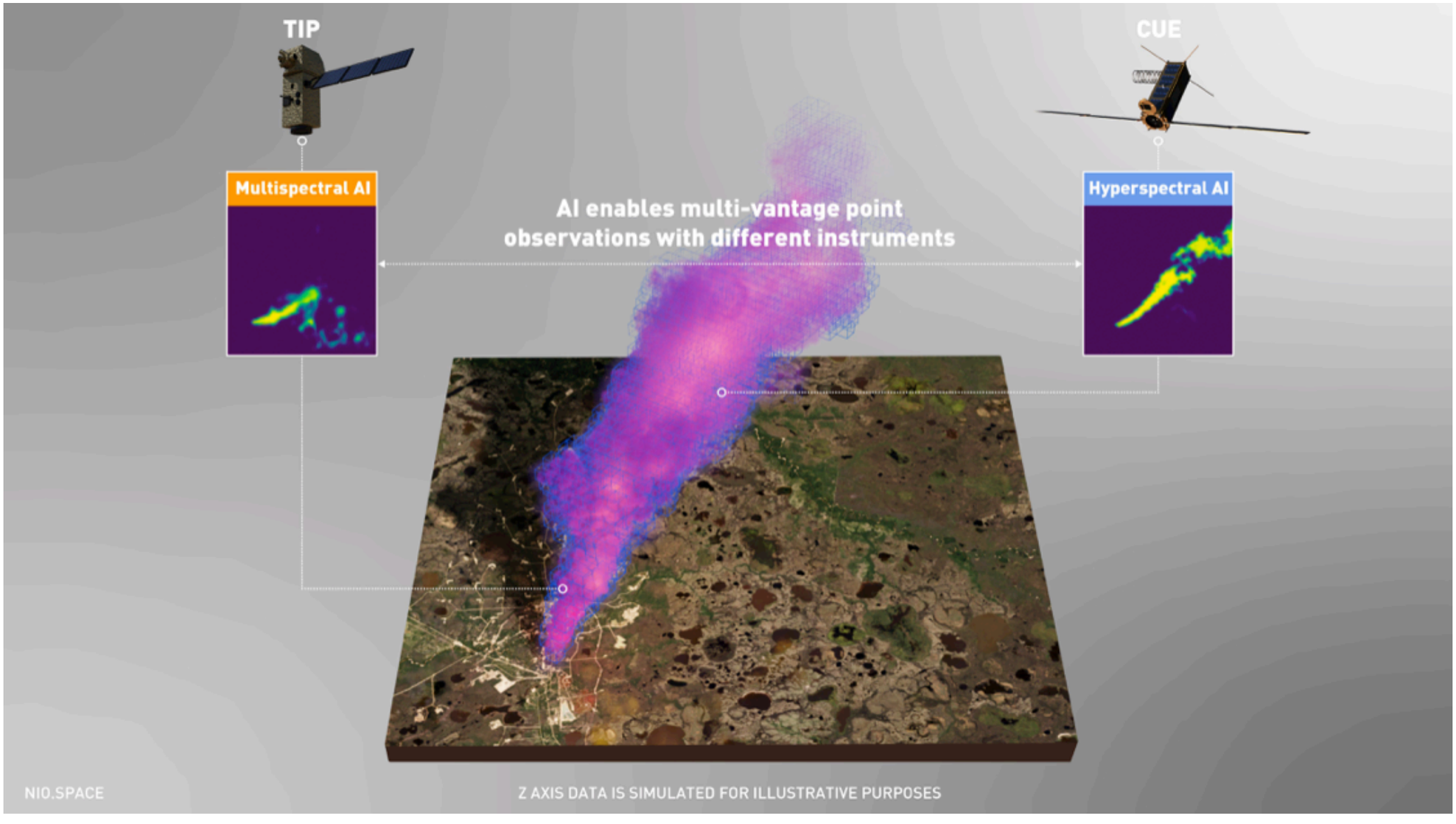
Data Center Power Optimization



Google DeepMind Blog, 2016

AI: 온실가스 누출 탐지

Detecting Greenhouse Gas Leaks



https://www.cs.ox.ac.uk/news/2218-full.html

탄소중립을 위한 AI활용

- 재생에너지 발전량 예측 모델 자동 생성
- 건축 설계 최적화: 단열·태양광 배치 자동 설계
- 정책 담당자를 위한 시나리오 보고서 자동 요약

- 드론·위성 영상으로 산림 훼손, 불법 배출 모니터링
- 카메라·센서로 공장 배출가스·누출 탐지
- 스마트미터를 통한 실시간 전력 수요 파악

- 재생에너지 발전략 예측
- 건물 냉난방 제어 알고리즘
- 교통 신호 최적화 (차량 배출 감소)

- 재생스마트그리드 자율 운영
- 재난 대응 에너지 관리
- 탄소배출권 거래 자동화

- 풍력·태양광 설비 점검 로봇
- 탄소 포집(CCUS) 시설 로봇 운영
- 사막 녹지화 로봇

전통적 AI

Perception AI (인지형 AI)

Generative AI (생성형 AI)

Agentic AI (에이전틱 AI)

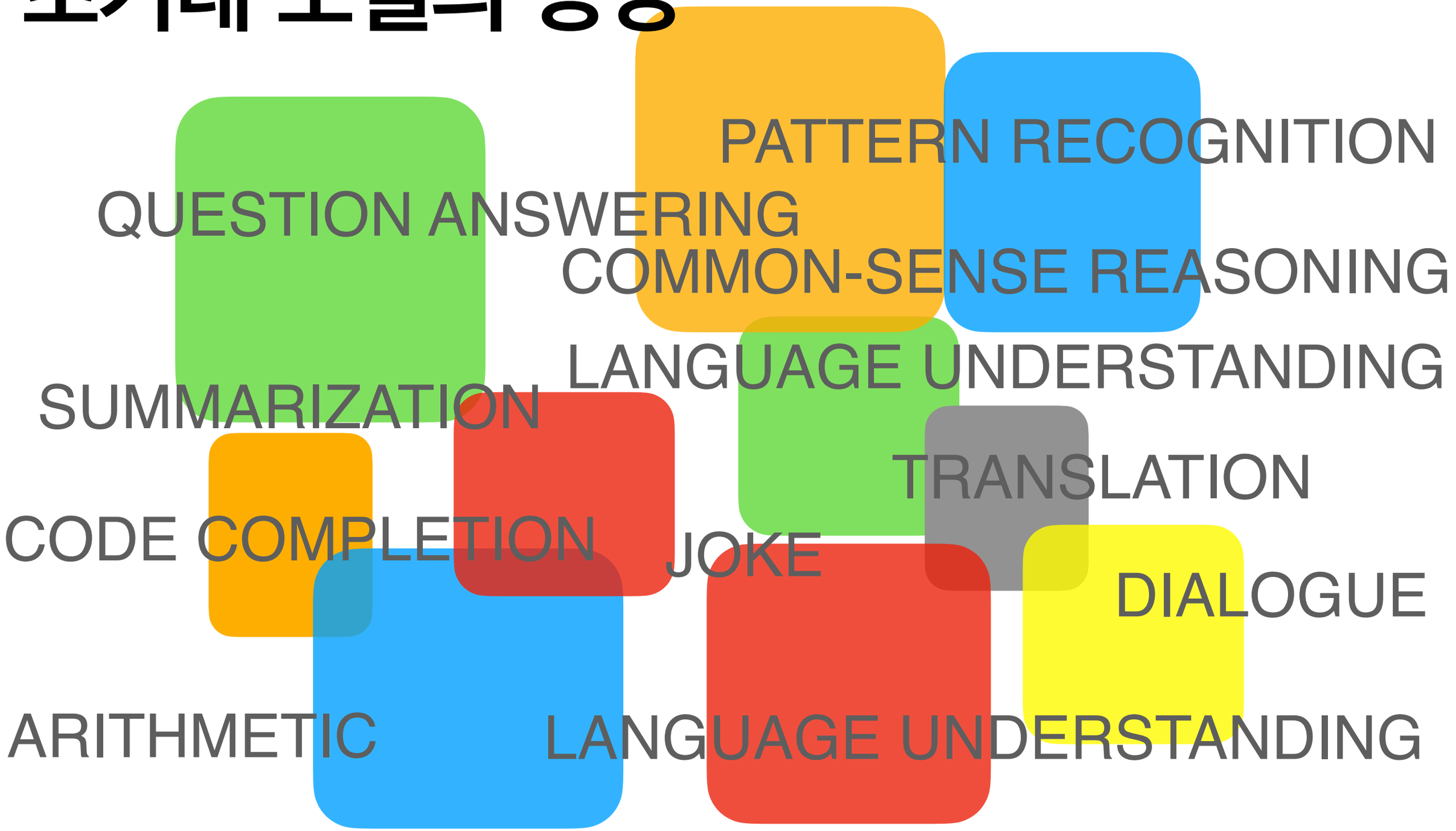
Physical AI (피지컬 AI)



The last 10 years was really about the science of AI, the next 10 years, we're going to have plenty of science of AI, but the next 10 years is going to be the application science of AI.

인공지능 리스크

초거대 모델의 등장



5,400억 개 파라미터

Source: Adapted from Google Research Blog (2022), “PaLM: Scaling to 540 Billion Parameters”

인공지능의 에너지 사용량

Energy footpring of AI

Joule

Commentary

The growing energy footprint of artificial intelligence

Alex de Vries[1,2,3,*]

chain of AI servers is likely to remain a bottleneck for several more years. NVIDIA's chip supplier, TSMC, is also struggling to expand its chip-on-wafer-on-substrate (CoWoS) packaging technology, which is essential for the delivery of chips that NVIDIA requires. TSMC is investing in a new CoWoS packaging plant, but this plant is not expected to begin volume production until 2027.[11] By this year, NVIDIA could be shipping 1.5 million of its AI server units, even as its market share is projected to decline.[10] Given a similar electricity consumption profile, these machines could have a combined power demand of 9.75–15.3 GW. Annually, this quantity of servers could consume 85.4–134.0 TWh of electricity. At this stage, these servers could represent a significant contribution to worldwide data center electricity consumption. With NVIDIA strongly outperforming analyst expectations during the first half of 2023,[7] the AI server supply chain is on track to deliver the projected growth. An important caveat to be considered in this scenario is that the utilization rates will likely be less than 100%, which will mitigate part of their potential electricity consumption. Another factor that should be considered is overhead electricity consumption (e.g., server cooling), which increases the total electricity consumption related to the AI server units.

In addition to hardware efficiency improvements, innovations in model architectures and algorithms could help to mitigate or even reduce AI-related electricity consumption in the long term. Google's Generalist Language Model (GLaM) was trained on 7 times the number of parameters included in GPT-3, but it required 2.8 times less energy for this process only 18 months after GPT-3 was trained.[2] However, this perspective overlooks Jevons' Paradox, which was formulated in 1865 and occurs when increasing efficiency results in increased demand, leading to a net increase in resource use. This effect has long been observed in the history of technological change and automation,[12] with recent examples in AI applications.[13] In fact, the sudden surge in interest in generative AI during 2022 and 2023, during which demand began to outstrip supply, could be part of such a rebound effect. Moreover, the improvements in model efficiency now allow single consumer-level GPUs to train AI models. This implies that the growth in AI-related electricity consumption will originate not only from new high-performance GPUs such as NVIDIA's A100 and H100 GPUs but also from more generic GPUs. It is already the case that former cryptocurrency miners using such GPUs have started to repurpose their computing power for AI-related tasks. Many of these GPUs were left redundant in September of 2022, when Ethereum, the second-largest cryptocurrency, replaced its energy-intensive mining algorithm with a more sustainable

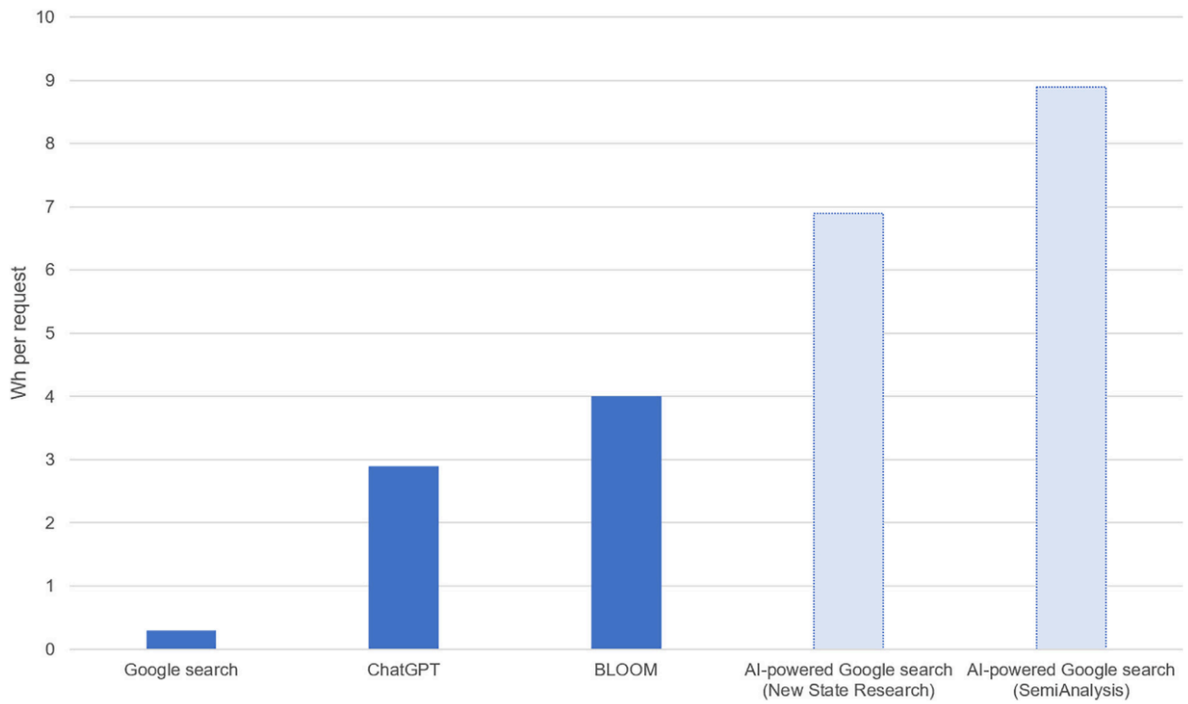
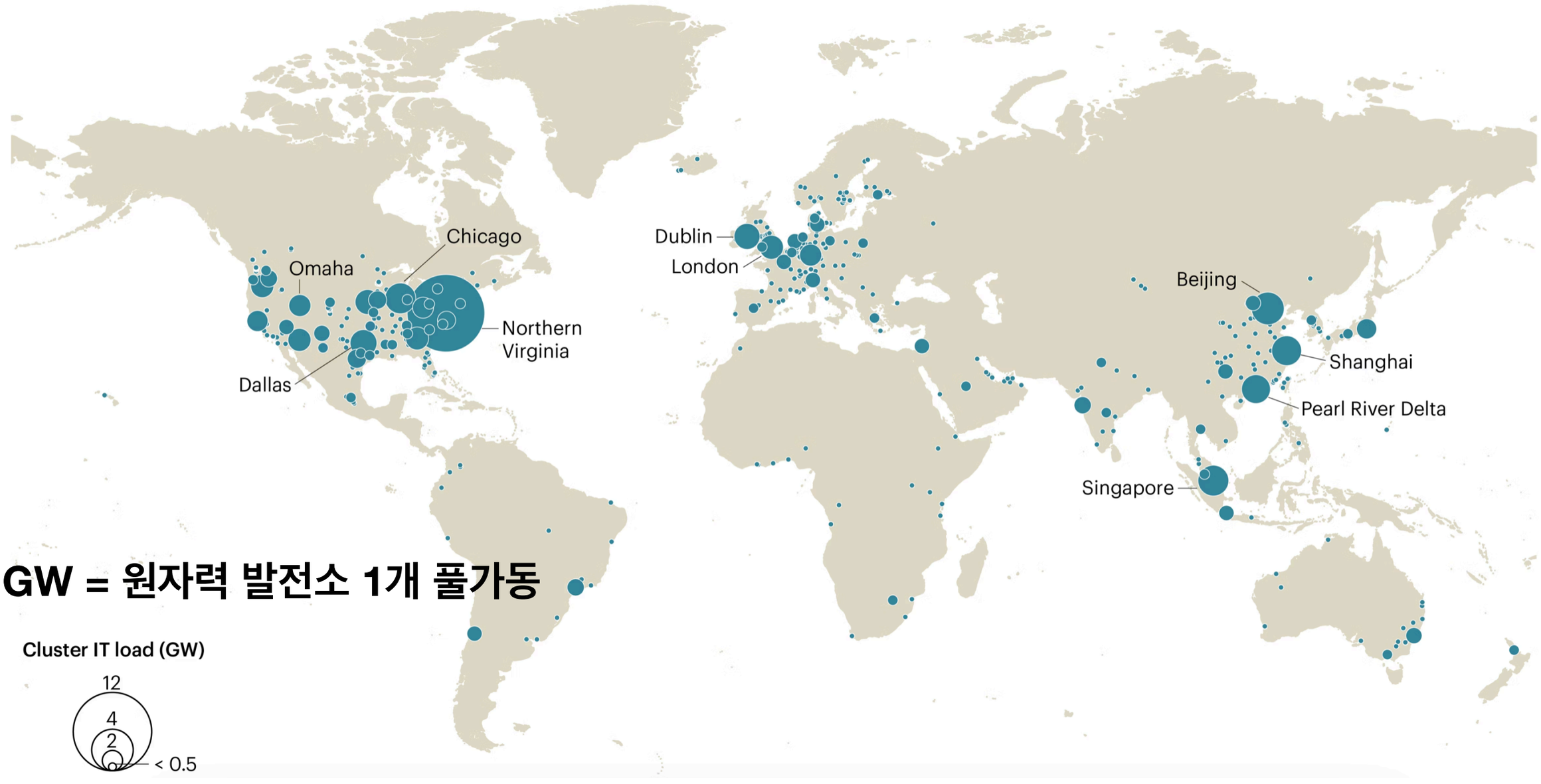


Figure 1. Estimated energy consumption per request for various AI-powered systems compared to a standard Google search

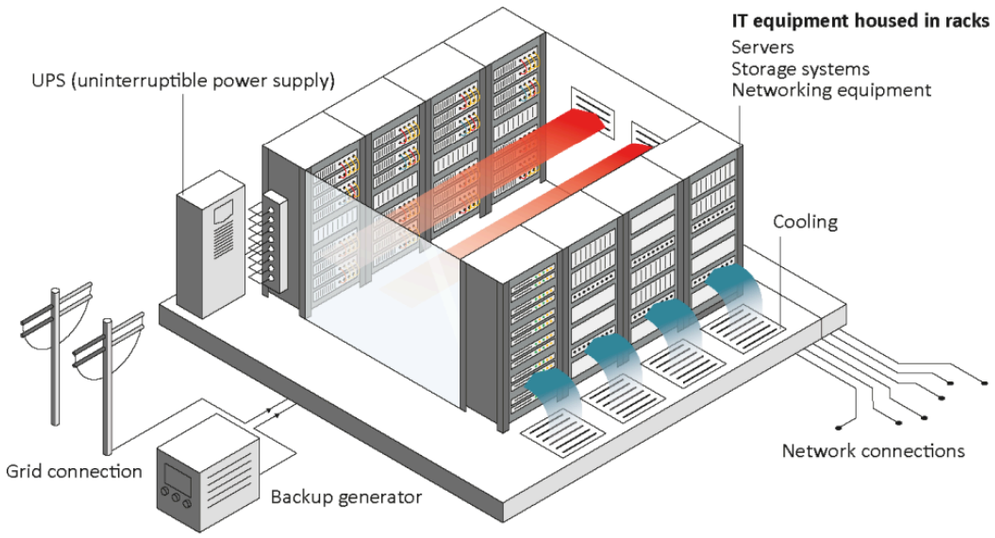
Alex de Vries (Joule, 2023)

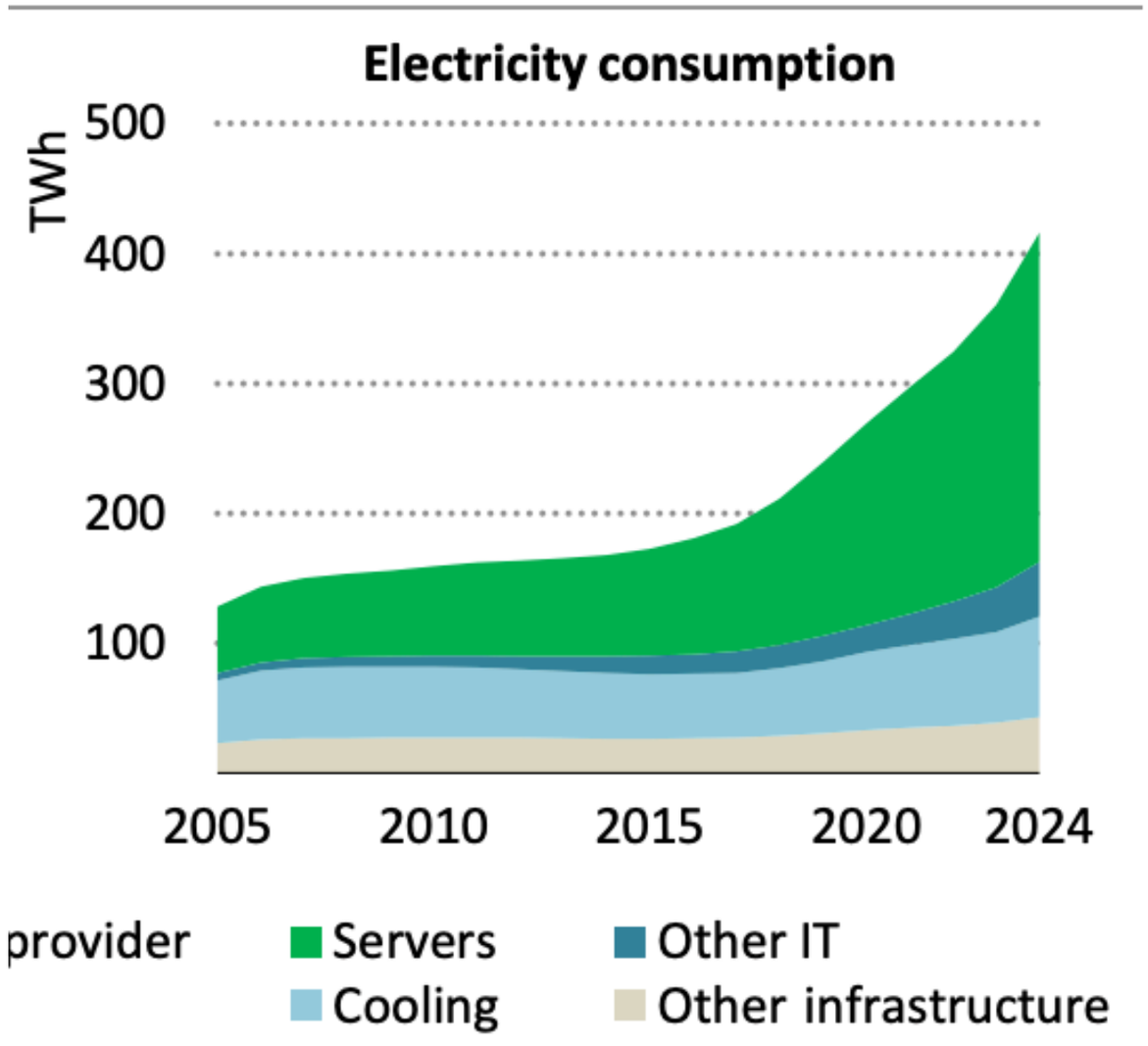
데이터센터의 에너지 사용량



IEA 2023; Energy and AI, https://www.iea.org/reports/energy-and-ai, License: CC BY 4.0

데이터센터의 에너지 사용량





전 세계 데이터센터의 총 전기 사용량

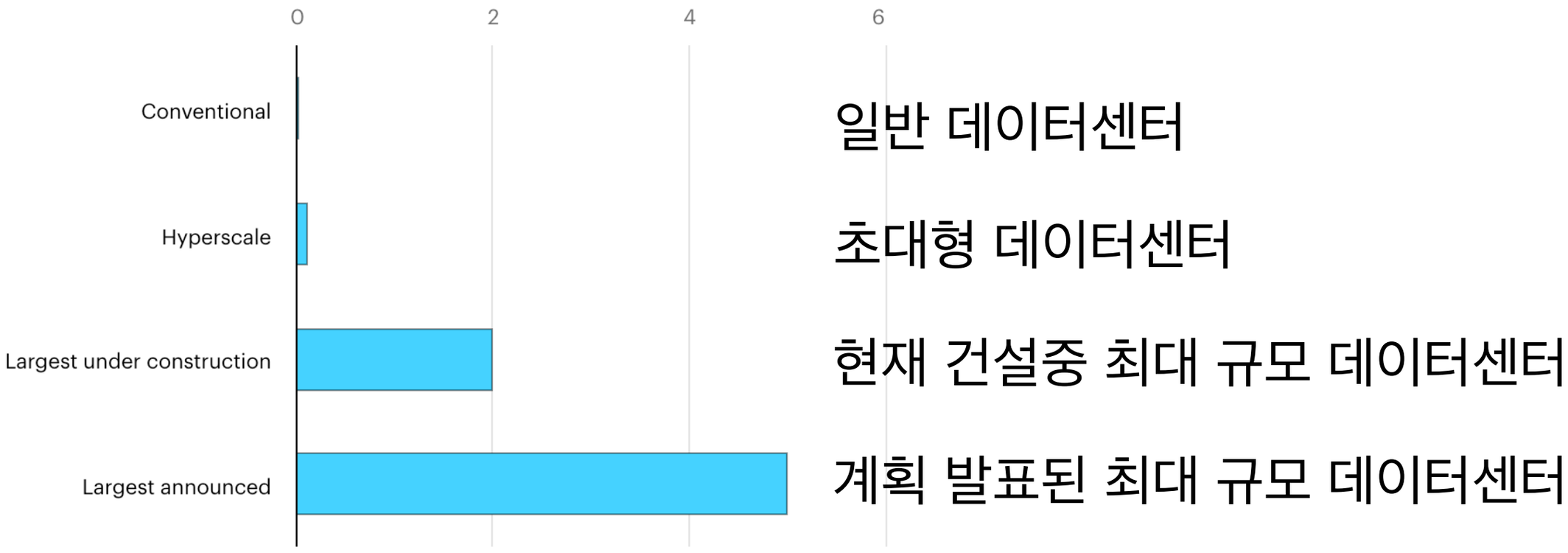
(참고: 2023년 한국 전력소비량은 592TWh)

IEA 2023; Energy and AI, https://www.iea.org/reports/energy-and-ai, License: CC BY 4.0

데이터센터의 에너지 사용량

Data centre electricity consumption in household electricity consumption equivalents, 2024

Open



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IEA 2023; Energy and AI, https://www.iea.org/reports/energy-and-ai, License: CC BY 4.0

데이터센터의 에너지 사용량

Meta Is Building The World's Largest AI Data Center, Covering 70 Football Fields

By Douglas McIntyre • March 31, 2025

Data centers could use 9% of US electricity by 2030, research institute says

By **Reuters**

May 30, 2024 12:32 AM GMT+9 · Updated May 30, 2024

Aa

AI 환각

Hallucination

PA summarise this article https://www.nytimes.com/2023/03/11/technology/chatgpt-prompts-to-avoid-content-filters.html

The article discusses how ChatGPT, an AI language model, is being used to circumvent content filters that are designed to detect and block certain types of content. By generating prompts that are less likely to trigger these filters, ChatGPT can be used to create content that might otherwise be censored. While this technology could be useful for those seeking to express themselves freely, it also raises concerns about the potential misuse of AI-generated content, as well as the difficulty of regulating such content in the future. The article concludes by noting that there is still much to learn about the impact of AI language models like ChatGPT on the way we communicate online.

Source: Wikimedia Commons, CC0 1.0

AI 환각

Hallucination

- Future of Life Institute – 공개서한 (2023, “Pause Giant AI Experiments”: GPT-4 이후 초거대 모델 개발을 잠정 중단하자는 요구.
- CAIS (Center for AI Safety) – AI 위험 성명 (2023): 전 세계 학자·CEO·연구자들이 서명.
- OpenAI/DeepMind 직원 공개서한 (2024, “Right to Warn”): 내부 직원들이 기업의 안전장치 부족과 위험 은폐를 고발.
- EU AI Act 논의 문서 / 규제 가이드라인 (2023~2024): 유럽 규제 차원에서 ‘거짓·오해를 일으키는 생성물’을 막아야 한다는 명시적 요구 → 환각 문제를 법제화.

AI 윤리적 문제

Ethical Issues

- 접근성 불평등 (Digital Divide): 선진국 중심의 인프라와 자원 독점, 개발도상국은 고성능 모델·데이터센터 접근 어려움
- 책임성과 투명성 (Accountability & Transparency): AI 의사결정 결과에 대한 책임 주체 불명확, 설명 가능성(Explainability) 부족
- 자원 사용 문제: 전력 + 물 소비, 초대형 AI 훈련은 엄청난 전력뿐 아니라 냉각을 위한 물도 대량 소비
- 데이터 편향 및 정의 (Fairness): AI가 학습하는 데이터는 주로 선진국 중심 → 기후 시뮬레이션·재생에너지 수요 예측 등에서 개발도상국 맥락이 반영되지 않을 수 있음.

탄소중립을 위한 AI

AI on the Path to Net Zero

- 기후위기는 더 이상 미래가 아닌 **현재의 위기**
- 탄소중립 달성 핵심 = **에너지 전환** (전력망·저장·효율화 혁신 필요)
- AI는 **예측·운영·효율화·유지보수 전 과정**에 활용 가능
- **데이터센터·스마트그리드·재생에너지 관리** 등에 이미 적용 중
- 기회 vs 리스크: **효율 향상과 에너지 소비 증가의 균형 관리** 필요
- 앞으로 더 창의적인 방식으로 **AI를 활용해 새로운 해법**을 만들어 갈 것