
ROCKY MOUNTAIN
INSTITUTE

Tōkyō's Electricity Revolution

東京の電力革命

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Brief for 小池 百合子, Governor of Tōkyō Prefecture
Renewable Energy Implementation Expert Board
18/19 June 2023 (virtual)

ピア・レビューを受けた統合的な設計に関する技術論文

ENVIRONMENTAL RESEARCH
LETTERS

EDITORIAL • OPEN ACCESS

How big is the energy efficiency resource?

Amory B Lovins[1]

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Environmental Research Letters, Volume 13, Number 9

Citation Amory B Lovins 2018 *Environ. Res. Lett.* **13** 090401

https://doi.org/10.1088/1748-9326/aad965

What can integrative design do? (η ≡ end-use efficiency)

buildings: ~4–≥10η
automobiles: ~4–8η
trucks: ~3–4η
airplanes: ~3–8η
factories: ~2–3η old, ~2–10η new
use of steel, cement,…: >2η

so…world economy: ~5η, by ~2060
plus better conversion efficiency
from electrification and renewables

See “How big is the energy efficiency resource?”, *Environ. Res. Ltrs.* **13** (2018) 090401, https://doi.org/10.1088/1748-9326/aad965

エイモリー・ロビンス宅　コロラド州オールドスノーマス（1983年）

米国のオフィスビル：5年間で効率性は5–10倍に

（エネルギー源単位　kWh/m²・年; 米国のオフィスの中央値　~293; 2015 日本 ~483）

~277➡173
(–38%, later 43%)
2010 改修

284➡85 (–70%)
2013 改修

...➡108 (–63%)
2010–11 新築

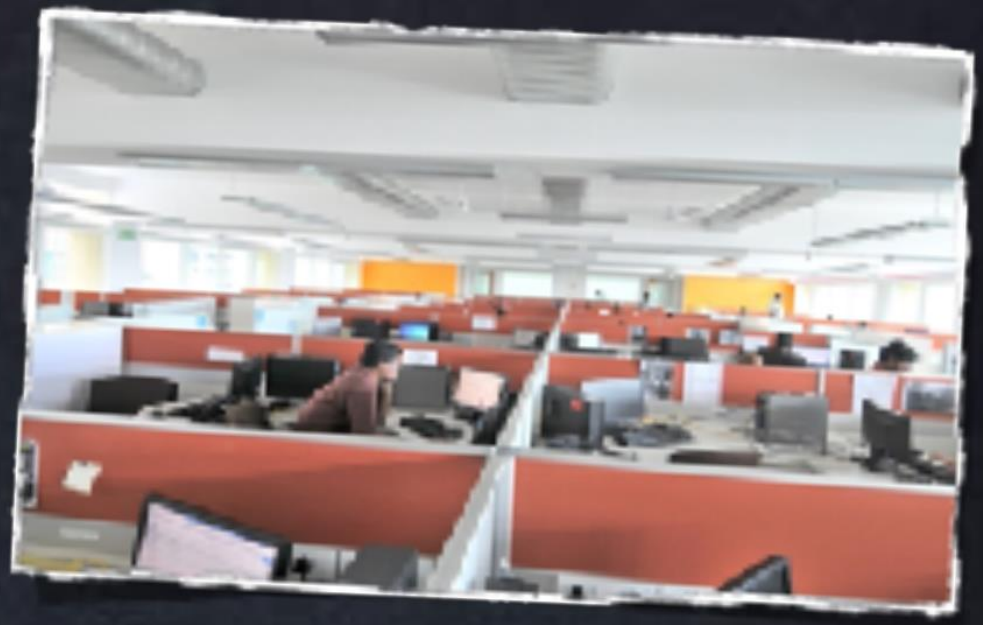
386➡107 (–72%)
2015 日本での改修

...36 (–88%)
2015 新築

...21 (–93%)
…そしてドイツの
2013年の新築
(オフィスと住居)

全ての技術は2005年よりずっと前から存在していた！

インドの新しい商業ビルは5倍以上の効率性

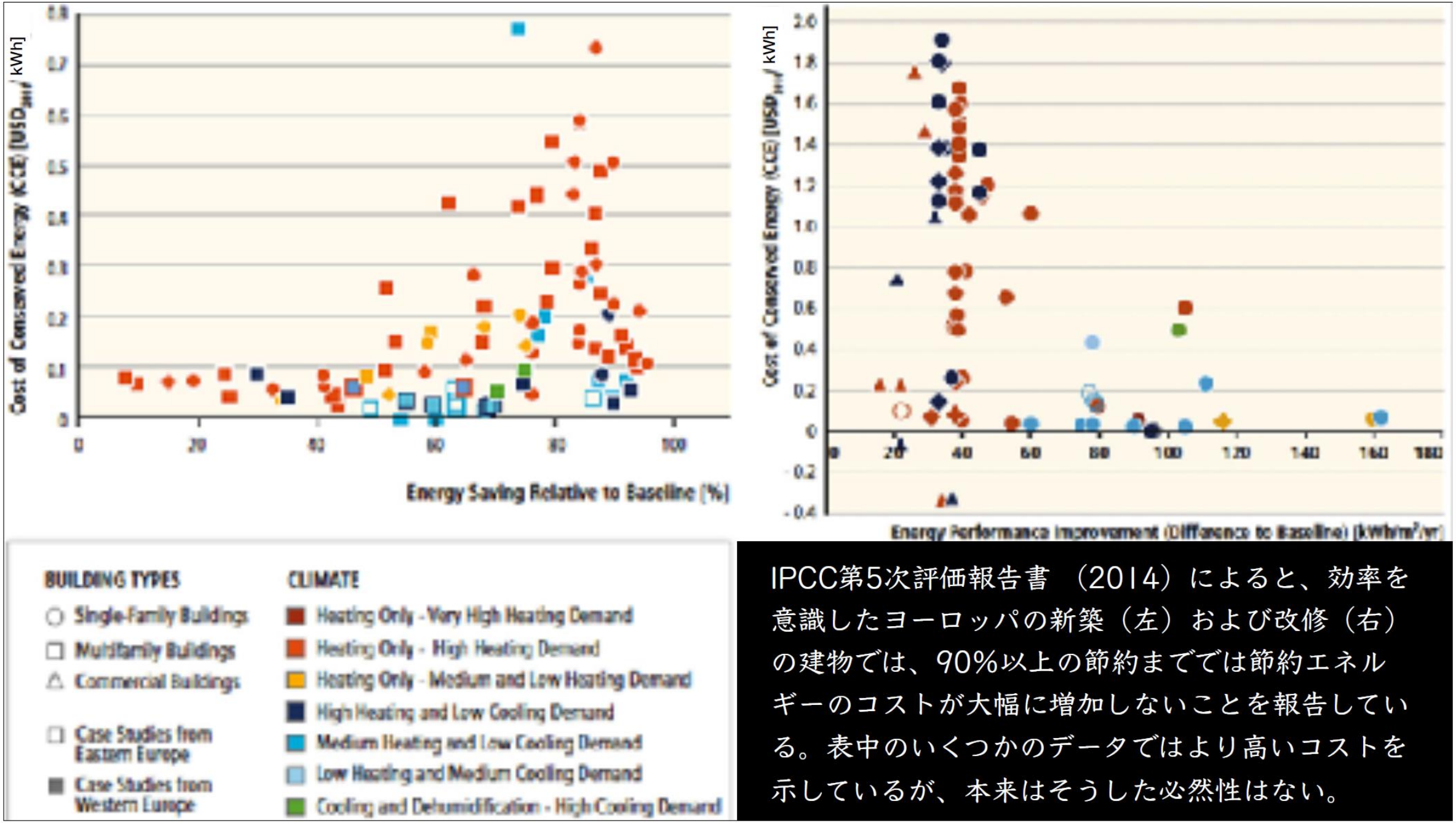


6つの街の22km²のオフィス地区にあるInfosysの150万m²のオフィス（2009–2014）

環境パフォーマンス指数は66kWh/m²・年に80%改善

初期投資は通常より10〜20%下がり、より快適に

Courtesy of Peter Rumsey PE FASHRAE (Senior Advisor, RMI) and Rohan Parikh (then at Infosys in Bengaluru, now at McBERL)



IPCC第5次評価報告書 （2014）によると、効率を意識したヨーロッパの新築（左）および改修（右）の建物では、90%以上の節約までては節約エネルギーのコストが大幅に増加しないことを報告している。表中のいくつかのデータではより高いコストを示しているが、本来はそうした必然性はない。

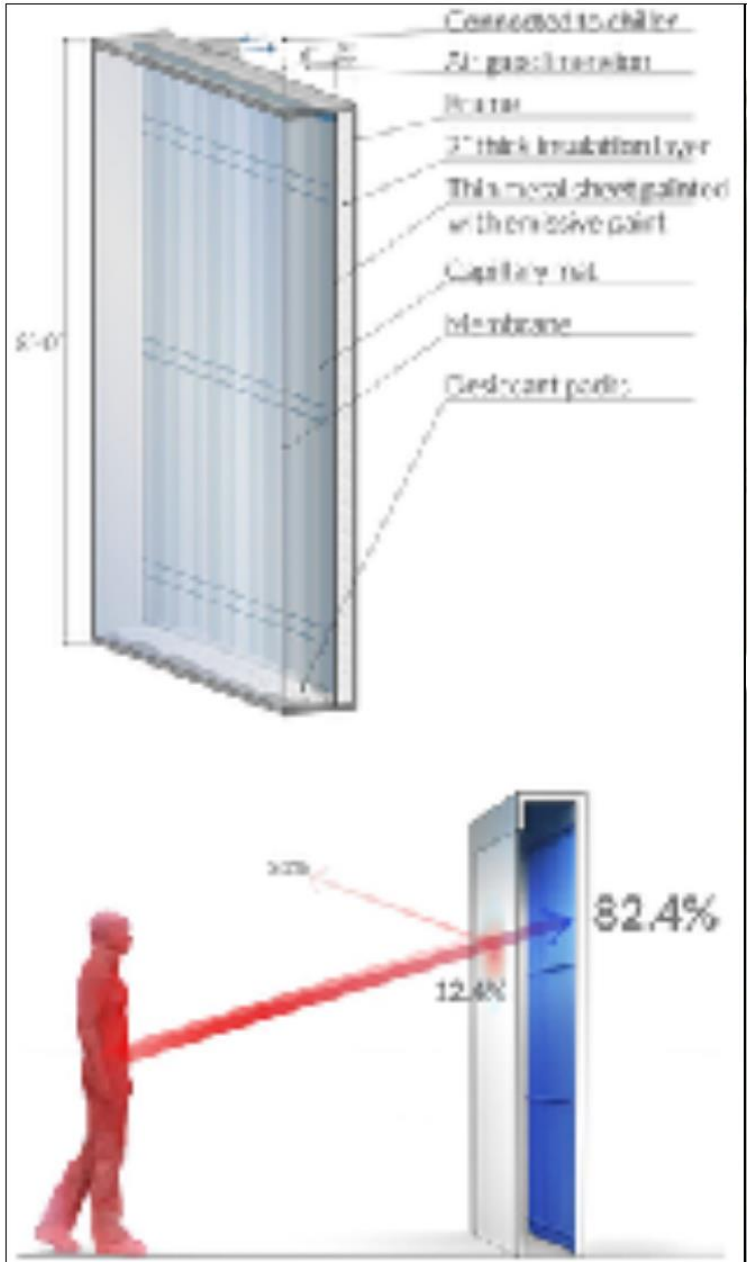
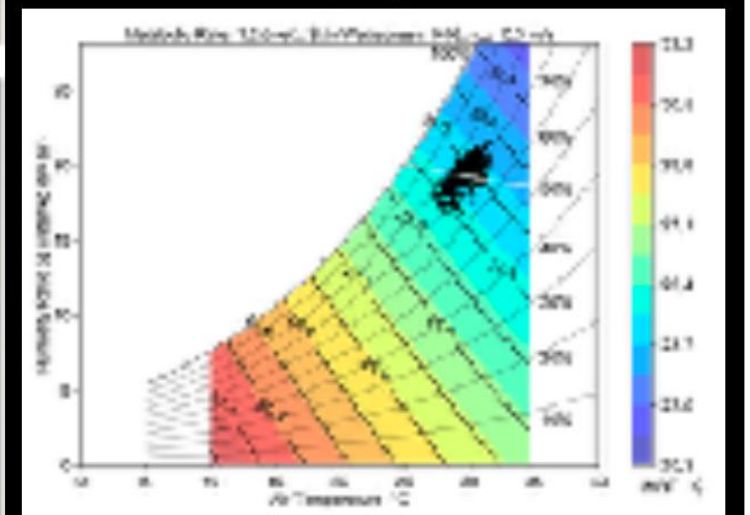


Fig. 2. The completed Cool Tube.

2019年の放射冷却ブレークスルー：

シンガポールの夏の屋外の
快適さを実現
日よけはあるが、
チラー、ファン、結露はない！

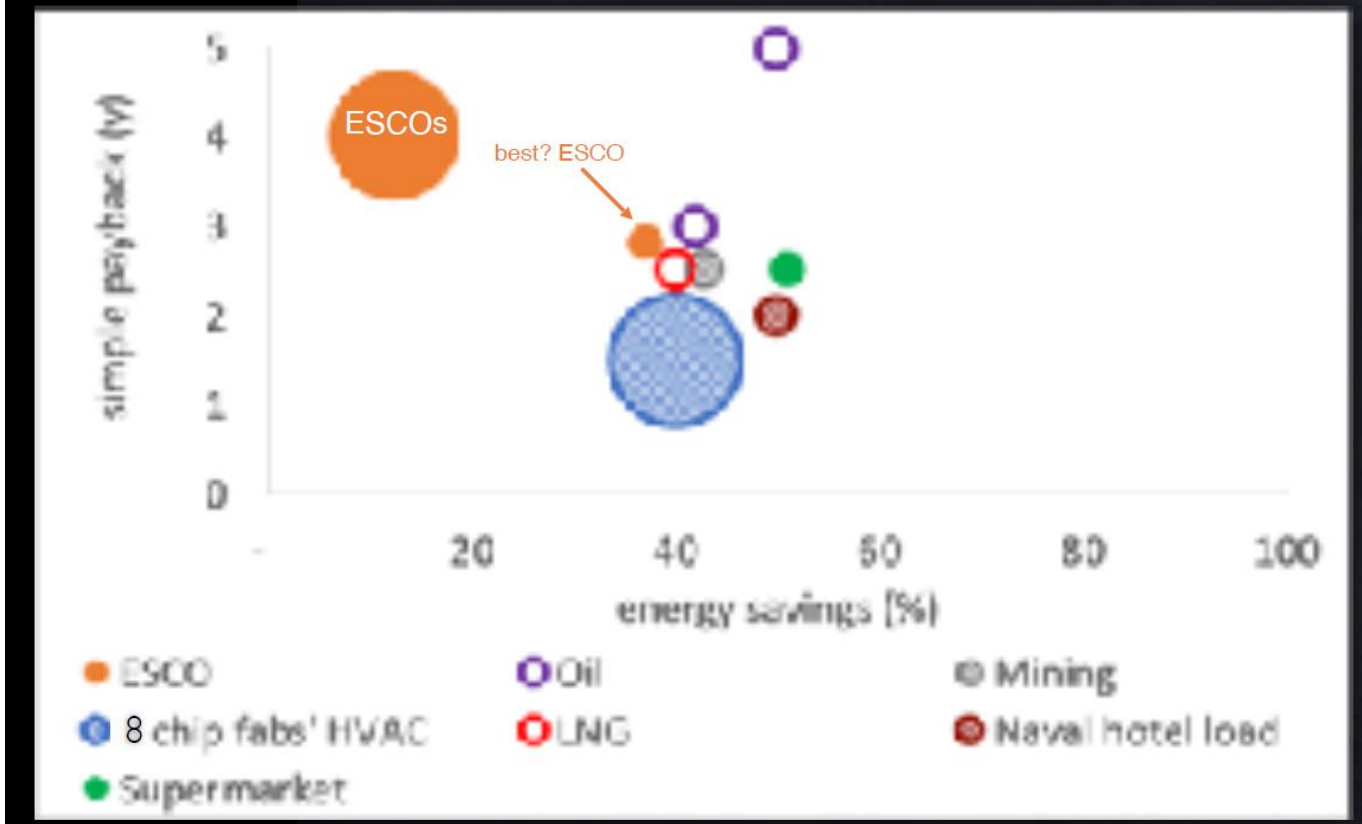


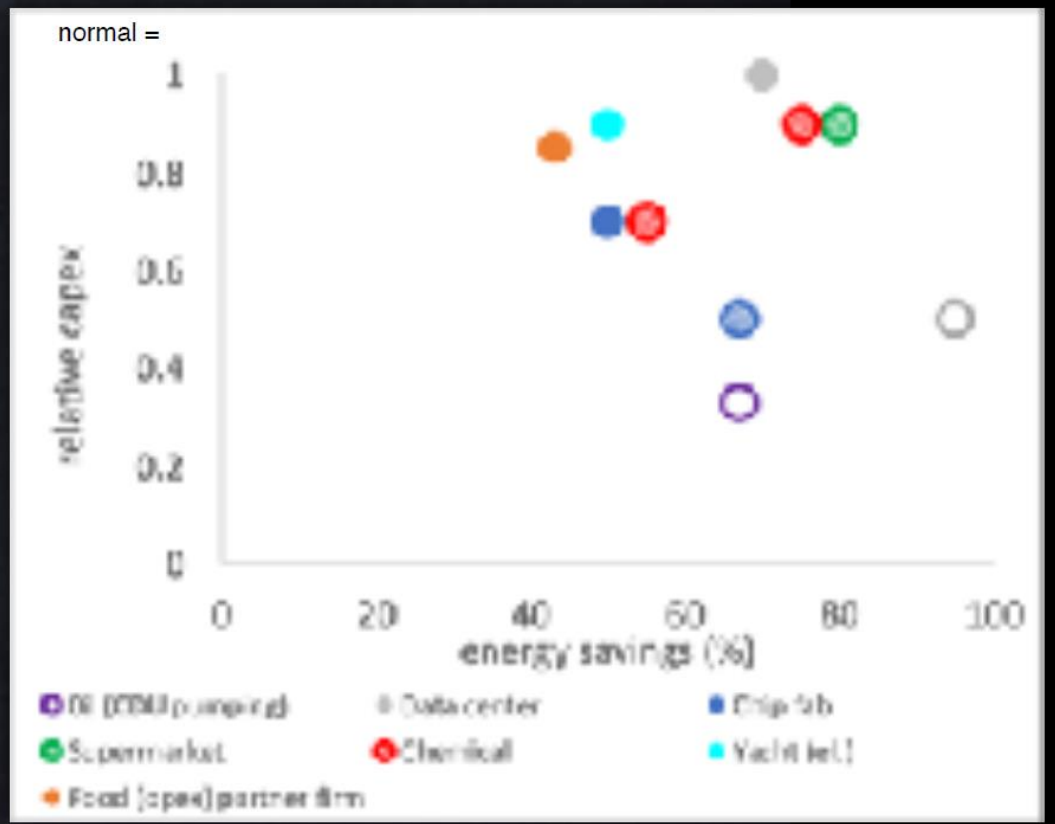
タイテルバルム他,米国科学アカデミー紀要,2019

E. Teitelbaum *et al.*, *Proc. Natl. Acad. Scis. [USA]* **117**(35):21162–21169, 1 Sep 2020, www.pnas.org/cgi/doi/10.1073/pnas.2001678117

RMI最新の600億ドルを超える価値のある、様々な産業プロジェクトにおける統合設計―改修と新築

（実線＝構築済み、影付き＝不完全なデータ、白抜き円＝未構築）





改修

新築

パイプとダクトにおける摩擦を約80～90%節約するように設計
これは世界の石炭火力発電所の約半分に相当

薄く、長く、曲がっている

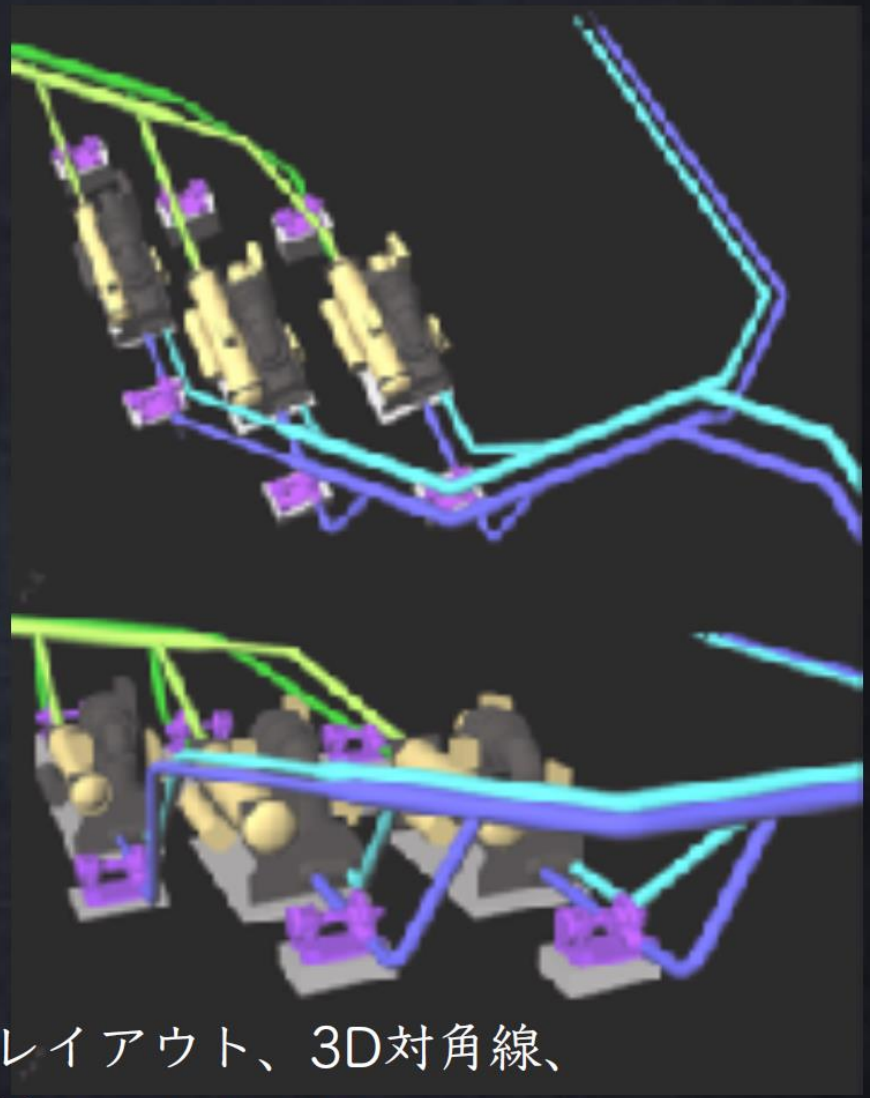
太く、短く、まっすぐ

典型的な投資回収 改修で1年以内　新築で0年

しかし、教科書、公式調査、または業界予測にはまだ含まれていない

パイプとダクトにおける摩擦を最大80～90+%節約するように設計
―太く、短く、まっすぐ

大きいパイプ, 小さいポンプ



非直交レイアウト、3D対角線、
少しの緩やかな曲がり

上質で質素な構造設計により
工業プロセスの熱を間接的に脱炭素化

張力構造—材料が約80～90%少ない

織物構造—材料が50%以上少ない

Mark West, *The Fabric Formwork Book*, Routledge, 2016; CAST (Centre for Architectural Structures and Technology), University of Manitoba, Winnipeg. See Hawkins *et al*'s 172-reference 2016 review, doi:10.1002/suco.201600117

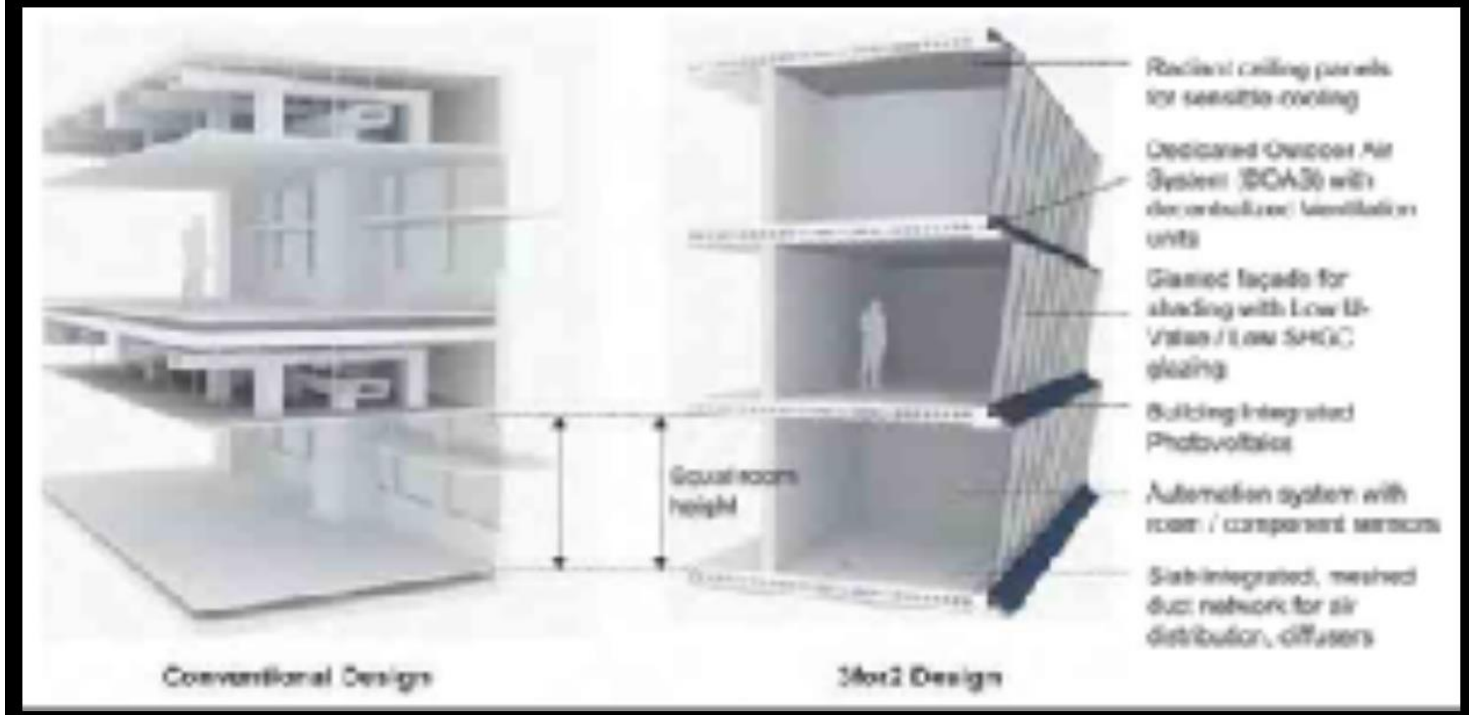
Schlaich Bergermann—see the remarkable book *Leicht Weit*

https://www.shapeways.com/blog/archives/35854-3d-printed-bridges-now.html (Joris Laarman Lab, MX3D)

アムステルダムの運河にある3Dプリントされた芸術的な12.5mのステンレス鋼橋

Three stories in the height of two: the magic of the negaplenum

UCWSEA pilot installation, Singapore, 2015



A. Schlueter *et al.*, "3for2: Realizing Spatial, Material, and Energy Savings through Integrated Design," *CTBUH J.* **2016**(2):40–45, Council on Tall Buildings and Urban Habitat

競争力のある炭素繊維電気自動車、2013～2022年

A. Lovins, SAE *J-STEEP*, 2020, https://doi/org/10.4271/13-01-01-0004

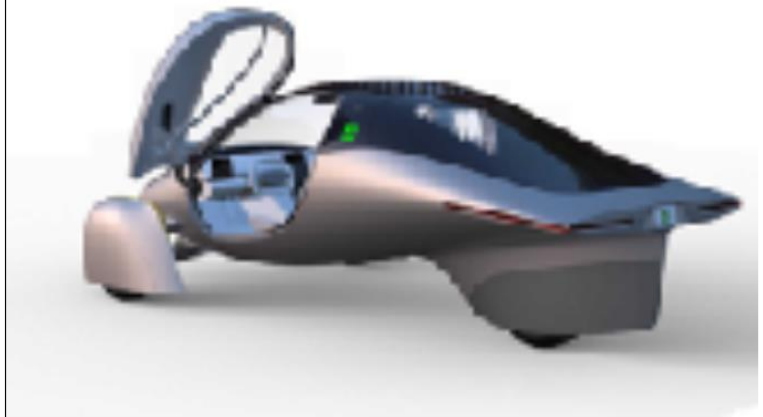
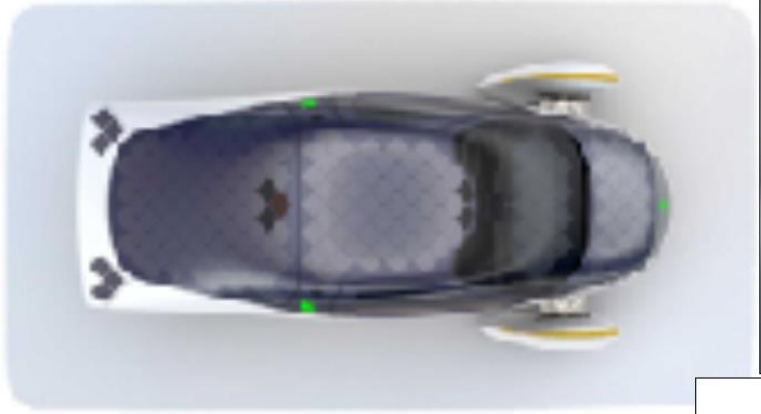
2013 BMW *i3*, http://www.superstreetonline.com/features/news/epcp-1303-bmw-i3-concept-coupe/

BMW MY2013's ~120–150-kg carbon-fiber-composite passenger cell; m_c 1,250 kg

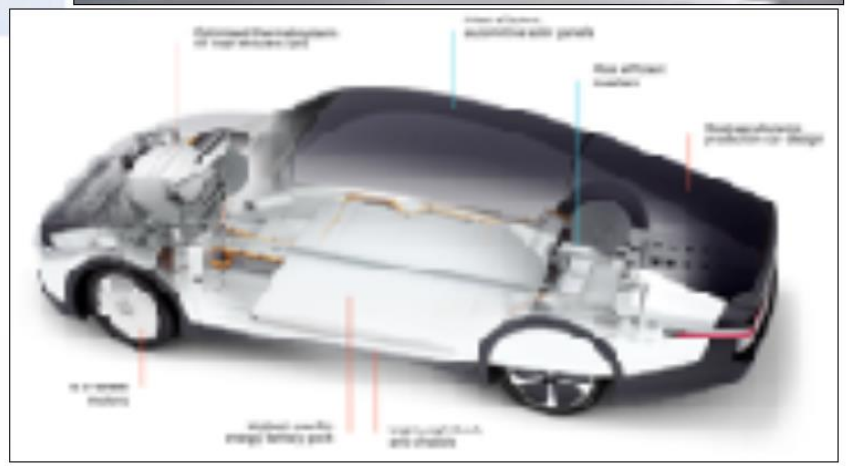
https://www.autocar.co.uk/car-news/industry/bmw-set-make-more-extensive-use-carbon-fibre

BMWのスポーティで1250kg、4倍高効率のi3モデルは、次の理由で初期モデルから利益を高めた

- バッテリーを減らし、 炭素繊維の費用を賄う（そしてより速く充電する）
- 53km/Lequiv（124 mpge）を提供
- 必要な資金は3分の2、水は約70%、エネルギー、スペース、時間は約50%少ない

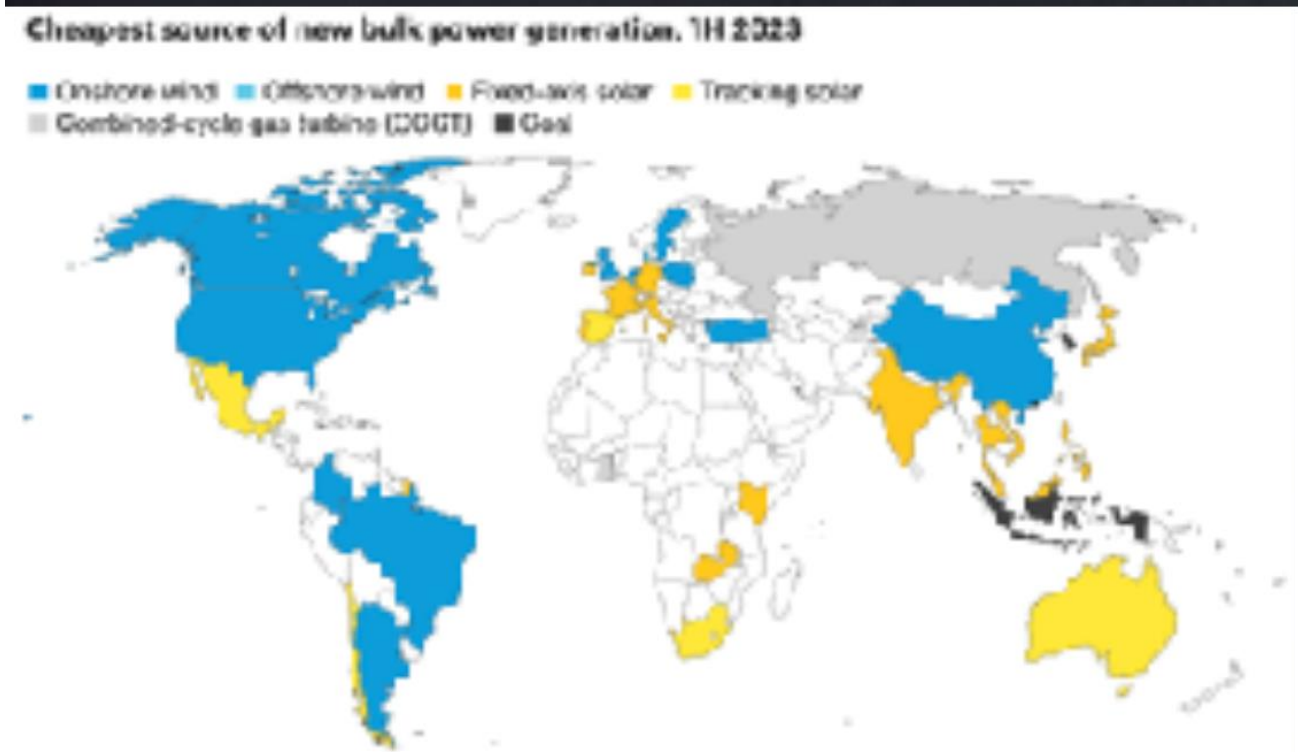




"NeverCharge" solar-powered Hypercar®-class 2-seat el. vehicle (aptera.us): up to 1,600-km range, but most drivers *will need no recharging*, because it's so efficient (**146 km/L_{equiv}**) that its solar cells capture enough energy for ~18,000 km/y. It has half a Tesla's mass, and less air drag (at C_d 0.13) than the side mirrors of a US pickup truck!; US$26–45k, dep. on range; raising production capital.

"Lightyear 0" mostly/all solar-powered (5 m^2, 21.5%-efficient PV, ~12 km charge/h) 5-seat 4-wheel sedan, 0.8–1.7 m^3 cargo, C_d 0.175, **107 km/L_{equiv}**, 725-km range. Production was suspended (Nov. 2022) to jump to the <€40k Lightyear 2 version (lightyear.one) in 2025 once it's recapitalized.

Sun &/or wind are now the cheapest source of new bulk electricity in countries with 85% of world GDP and 82% of electricity generation—including Japan



Source: BloombergNEF

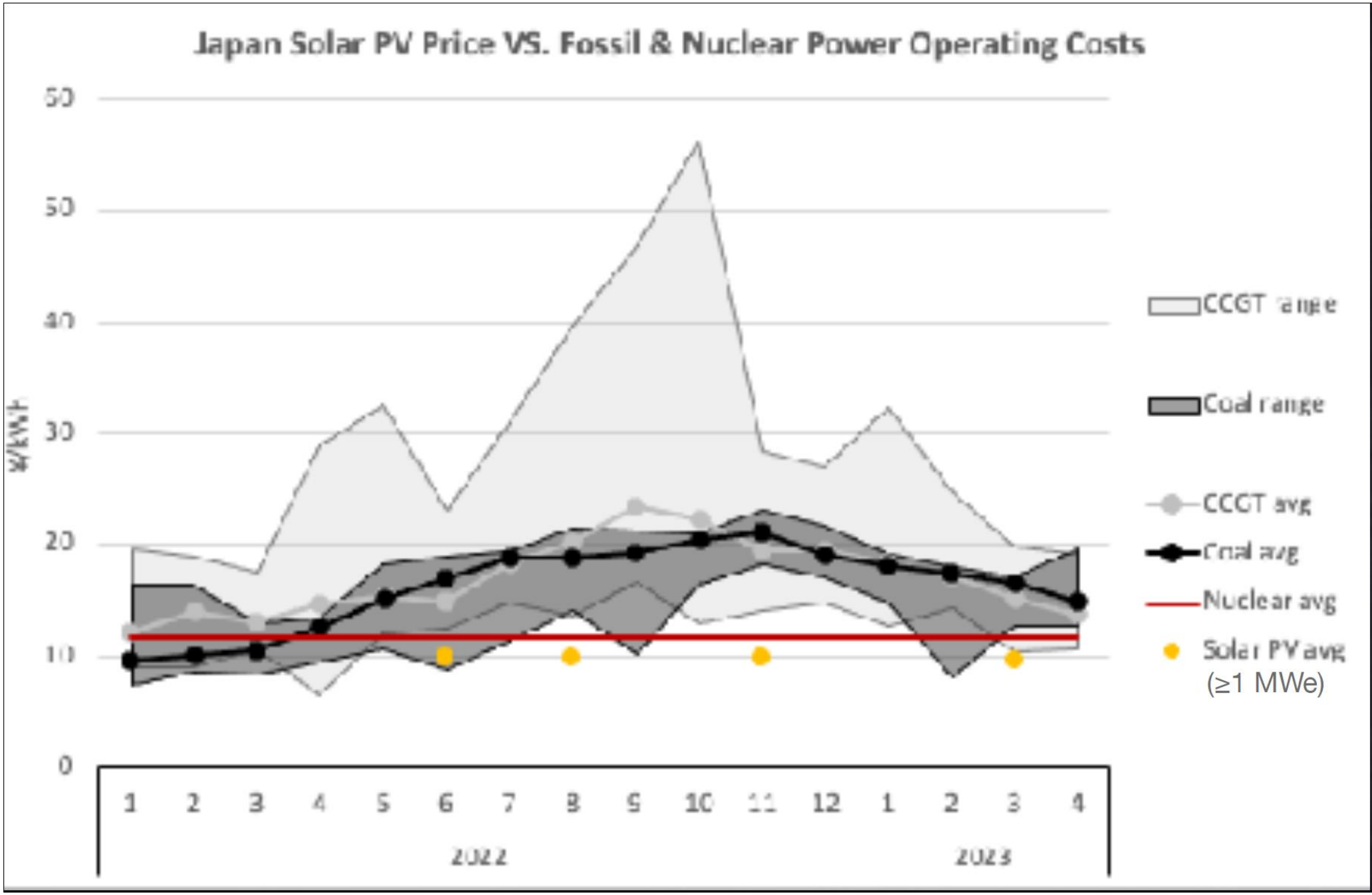
Note: Shows the technology with the lowest LCOE for auction bid for recent delivery for new-build plants in each market where BNEF has data. LCOEs exclude subsidies, tax credits and grid connection costs, and include a carbon price where applicable.

v10.1 (08 June 2023): Initial release

"Variable renewables and back-up are the cheapest new-build option to meet a flat load." The backup can be demand-side, storage, other renewables, or nonrenewables (generally the costliest).

Estimated mid-2022 learning curves (% cost reduction per doubling of cumulative capacity) were 28.8% for PV modules, 12% for onshore wind projects (13.6% for turbines), ~18% for lithium battery packs (to ≥2030), 0 for coal and gas-fired CCGT, negative for nuclear.

Bloomberg New Energy Finance, 04 June 2023, https://www.bnef.com/insights/31487, based on actual costs of 31,000 projects worldwide

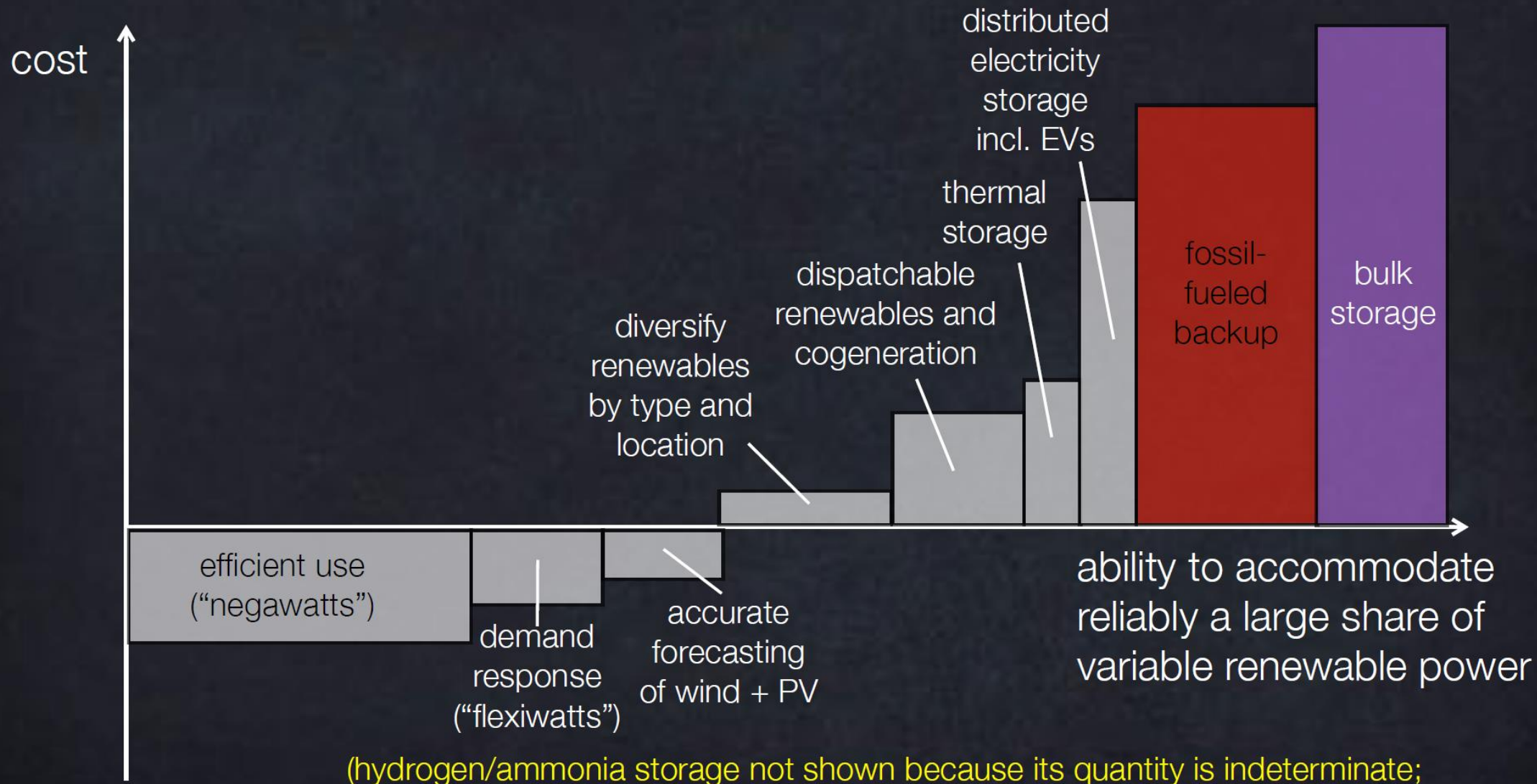


• For existing coal and CCGT power plants: the operating cost is essentially the fuel cost observed (i.e., imported steam coal and LNG). Operation & maintenance cost is ¥3/kWh for coal and ¥1/kWh for CCGT. Electrical conversion efficiency is 40% for coal and 55% for CCGT. Capacity factor is 75% for both coal and CCGT. No carbon cost is included (because it is currently negligible in Japan). Initial investment is assumed fully amortized.
• For nuclear power plants: based on restarted reactors. Operating cost includes restart cost (i.e., safety upgrades), fuel cost, and operation & maintenance cost. Capacity factor is 70%. Initial investment is assumed fully amortized. Lifetime extensions included when granted.
• For solar PV: based on auctions for projects ≥ 1 MW. Price includes total cost and profit. After auctions, solar PV power plants should typically start operation within 3 years.

Steam coal and LNG from Japan MoF, nuclear from Professor K. Oshima (Ryukoku University), and solar PV from OCCTO.
Courtesy of Dr Romain Zissler, Renewable Energy Institute, Tōkyō, 18 June 2023. Consistent with https://www.bnef.com/flagships/lcoe, 11 June 2023.

Grid flexibility resources

(all values shown are conceptual and illustrative)



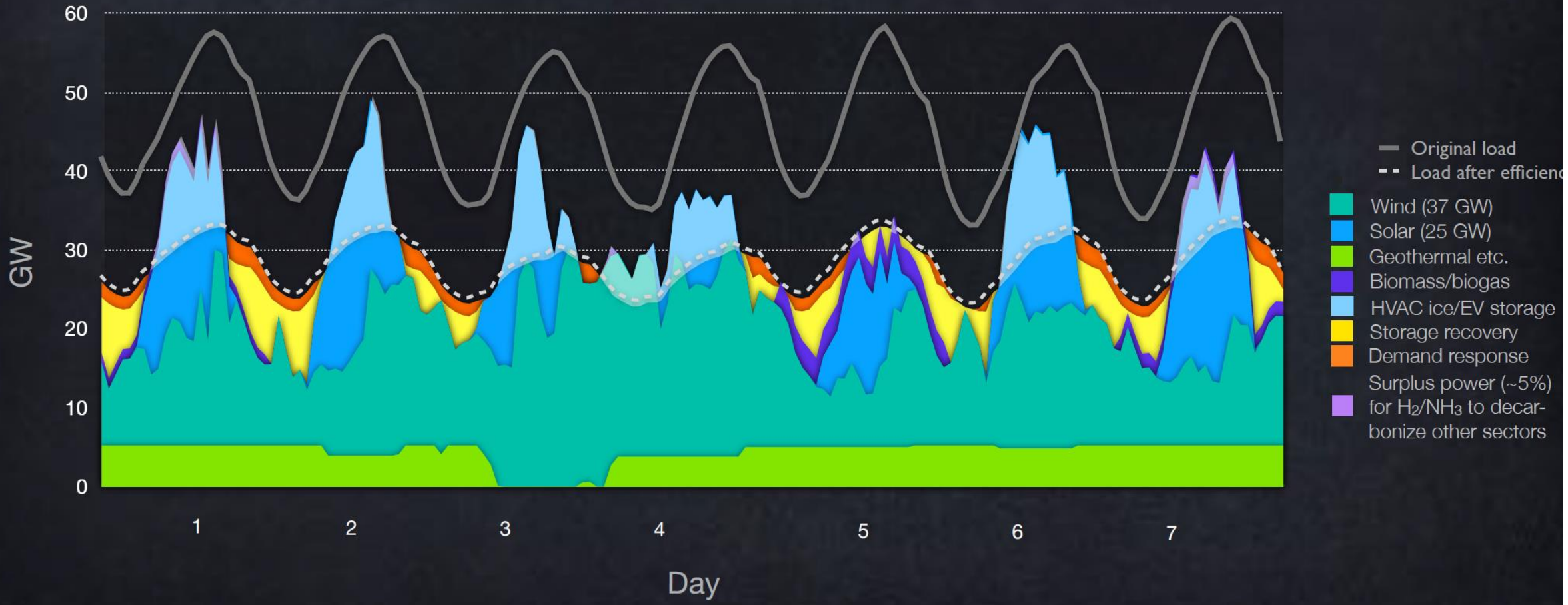
(hydrogen/ammonia storage not shown because its quantity is indeterminate;
"bulk storage" combines batteries with pumped hydro, compressed air, gravity,…)

Choreographing Variable Renewable Generation

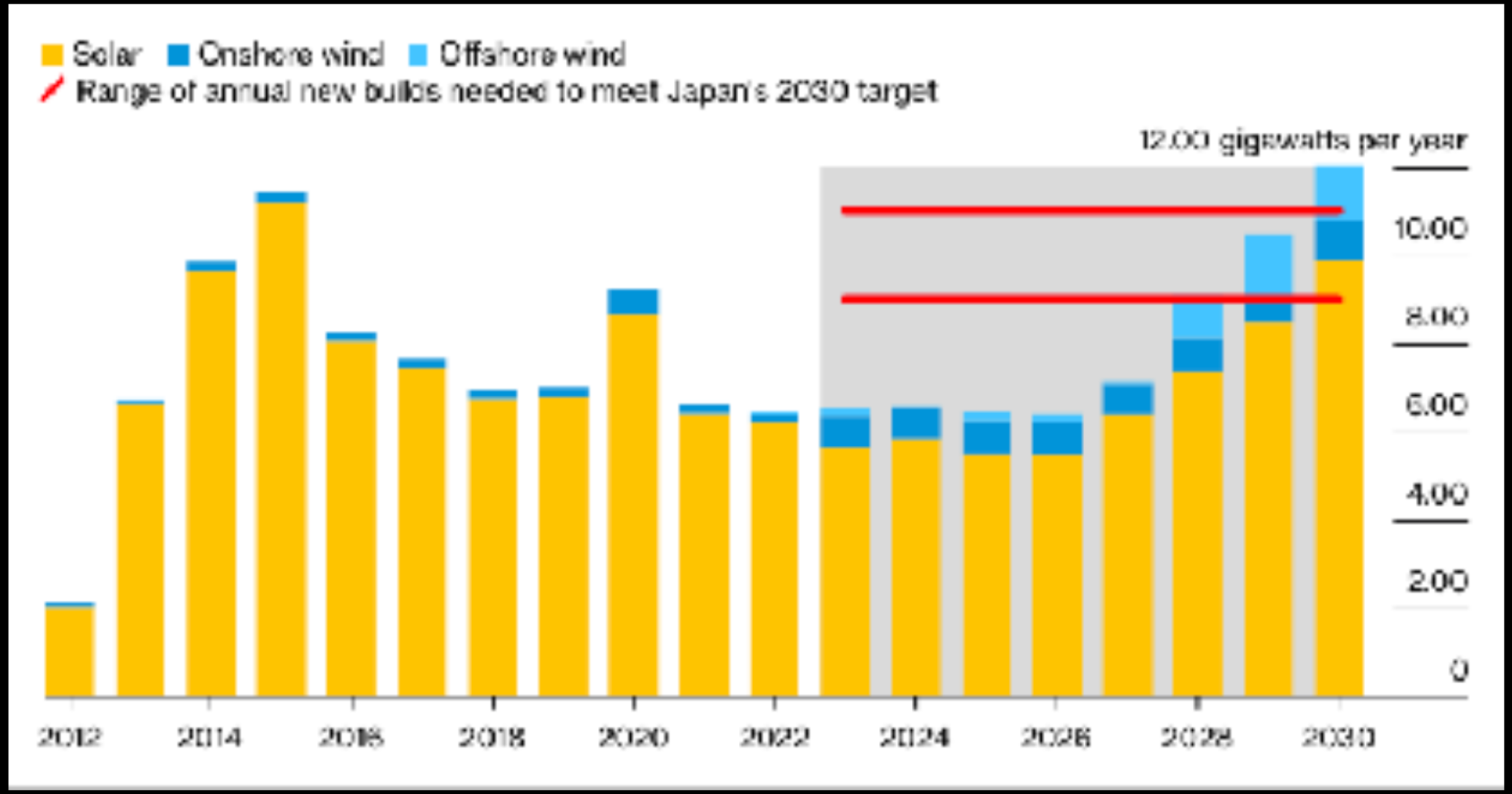
変動型再生可能エネルギーの計画的発電

ERCOT power pool, Texas summer week, 2050 (RMI hourly simulation, 2004 renewables data, projected from 2009–10; an update would scale both loads and supplies for the same conclusion)

テキサス電力信頼度協議会（ERCOT）電力プール、テキサス州における２０５０年夏の１週間（RMI による時間ごとのシミュレーション）



Japan would need 9–11 GW/y of carbon-free energy deployment over 2023–30 to meet its 2030 carbon target; actual solar+wind addition in 2022 was 6.5 GW



https://www.bnef.com/insights/31555, 07 June 2023

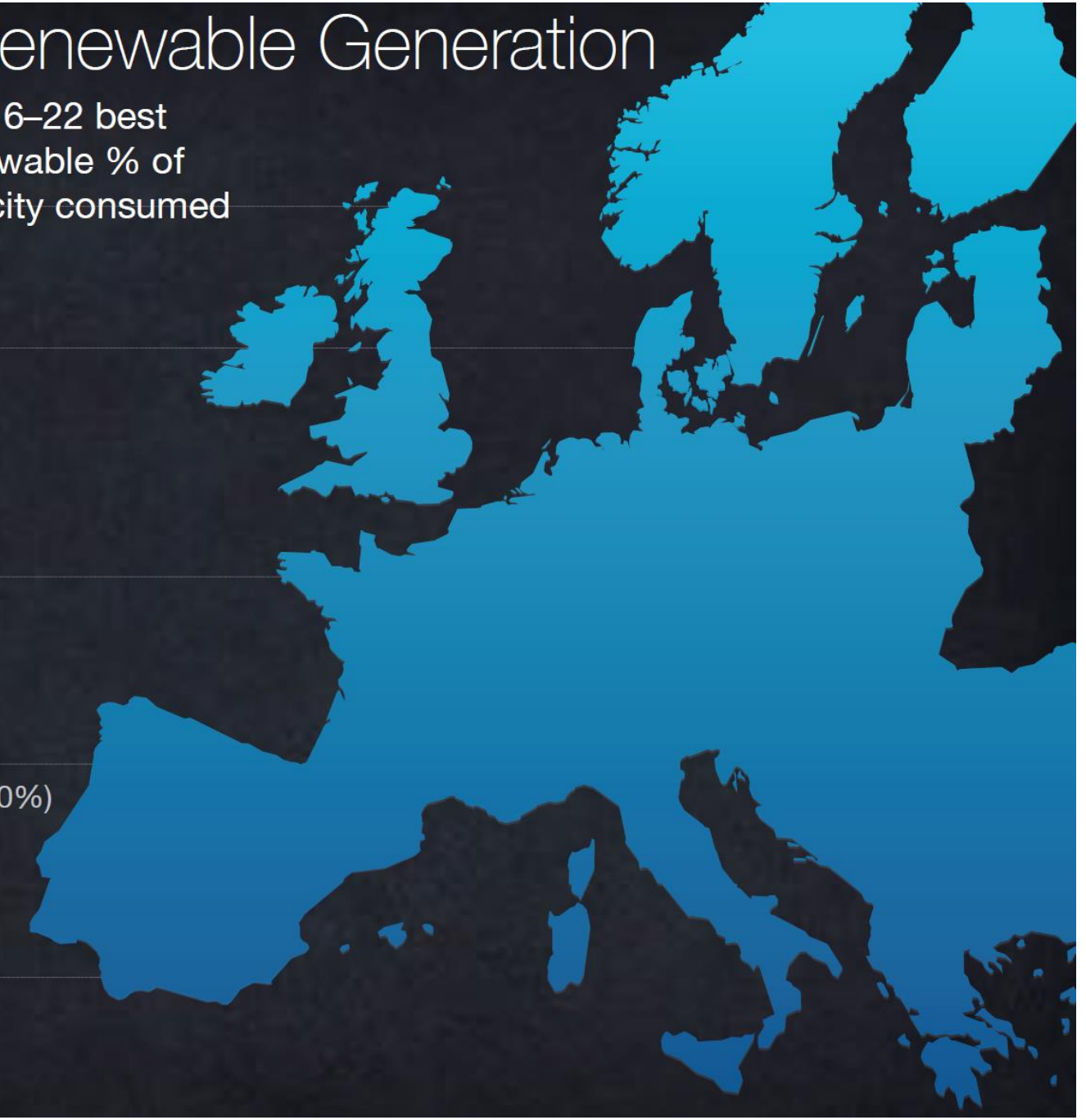
Variable Renewables Can Be Forecasted At Least as Accurately as Electricity Demand

French windpower output, December 2011: forecasted one day ahead vs. actual

Source: Bernard Chabot, 10 April 2013, Fig. 7, www.renewablesinternational.net/wind-power-statistics-by-the-hour/150/505/61845/, data from French TSO RTE

Choreographing Variable Renewable Generation

Europe, 2016–22 best annual renewable % of total electricity consumed



99%

Scotland 2020 (79% without hydro)

83%

Denmark 2021 (61% windpower)

52%

Germany 2020 (2016 peak 88%, 2018–20 ~90–100%, >100% for 12 h 27–28 Mar 2021)

66%

Portugal (2018, 42% without hydro) (2011 & 2016 peak 100%)

46%

Peninsular Spain (2016 & 2020, 27/33% without hydro)

Japan can lead this global energy *hiyaku*

日本は、世界のエネルギーの飛躍を牽引することができる

Japanese frogs jump too!
日本の蛙も飛躍する!

The old pond
frog jumps in
plop
—Bashō, 1686

古池や
蛙飛び込む
水の音

ご静聴ありがとうございます