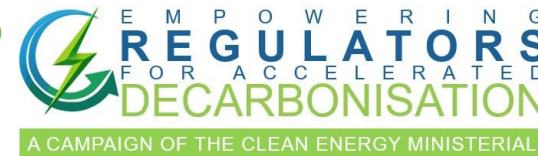




2026 Thought Leadership Report on Strategic Electrification

Enabling strategies for energy security, affordability and reliability



Acknowledgement

We gratefully acknowledge the contributions of all individuals and organizations mentioned in this report that supported its development. The International Renewable Energy Agency (IRENA) and the Industrial Deep Decarbonization Initiative (IDDI) Secretariat, coordinated by UNIDO, also provided thought leadership and technical input to this report.

We also appreciate and acknowledge the contributions of the report's advisory panel and reviewers for their guidance and critical feedback throughout the drafting process.

We greatly appreciate the editorial and design teams for their dedication in ensuring the report's clarity and accessibility, and to everyone else who contributed both directly and indirectly to its publication.

Summary for policy makers: Five key insights

#	Message	Why it matters
1	Electrification is a security strategy – but only if the power system is ready	Electrification can reduce exposure to volatile fossil fuels – but only if countries can deliver clean power reliably where and when demand appears. Energy security's center of gravity therefore shifts from fuel procurement to system capability: grids, flexibility, storage, efficient demand, supply chains and institutions.
2	Demand growth must be planned and shaped <i>before</i> it appears on the grid	New demand from EVs, cooling, data centers, industrial electrification, hydrogen and other large loads is becoming more locational, peaky and conditional. Countries that see future load by place, hour, credibility and flexibility can avoid distorted queues, poorly sequenced investment and unnecessary peak-driven costs.
3	Demand-side efficiency lowers infrastructure needs and improves affordability	Every inefficient appliance, cooling unit or electric product sold today becomes demand the power system must serve for years. Efficiency standards, labels and demand-response-ready products reduce bills and defer grid and generation investment before those costs are locked in.
4	Affordability depends on valuing flexibility before costs are locked in	The political risk is not only high electricity prices; it is avoidable system cost becoming unavoidable consumer cost. Least-cost electrification requires planners and regulators to compare grids, flexibility, efficiency, storage and alternatives to reinforcement before peak-driven investment becomes the default.
5	Grid modernization requires building more <i>and</i> using the existing system more effectively	New infrastructure is essential, but it often arrives slower than demand growth, renewables and connection requests. Relying on buildout alone can raise bills, lengthen queues and leave costly capacity underused. Governments can move faster by pairing durable grid expansion with practical tools that unlock existing capacity: hosting-capacity maps, flexible connections, grid-enhancing technologies, distributed resources and local flexibility procurement.

Where CEM can add concrete value

CEM can help countries accelerate progress through practical cooperation: shared diagnostics, country Action Plans, action-oriented workshops, shared leading practices for peer learning that continue beyond Riyadh.

Track	Concrete focus	Likely contributors
Demand growth planning exchange	Help countries build bottom-up hourly demand profiles for EVs, cooling, data centers, industrial electrification, hydrogen and other large loads; compare large-load transparency, distribution-level data, credible demand signals, participatory planning and integration of efficiency/flexibility into forecasts.	LTES/GCEP, SEAD, ISGAN WGs6+7, EVI, IDDI, ERAD, UNIDO, planners, regulators, cities, TSOs/DSOs, large users, industry ministries, procurement bodies and large buyers.
Grid utilization and flexibility track	Compare practical approaches to hosting-capacity maps, non-firm/flexible connections, queue reform, GETs/ATTs, DER/VPP integration, local flexibility procurement, demand-side flexibility valuation and regulatory readiness for non-wire alternatives.	ISGAN WGs3+6+9, GPFM, UNIDO, ERAD, regulators, system operators, utilities, aggregators, technology providers, finance actors.
Affordability and consumers learning stream	Compare how countries protect consumers while enabling efficient products, trusted tariffs, flexibility participation, non-wire alternatives and adoption finance.	SEAD, ISGAN WG9, GPFM, regulators, utilities, consumer agencies, finance actors.
Reliability, resilience and risk exchange	Create a non-sensitive exchange on fuel exposure, cyber-by-design, physical resilience, supply-chain bottlenecks, sector coupling and critical-load planning.	System operators, cyber/resilience agencies, ministries, reliability bodies, UNIDO, IRENA, ISGAN partners.
Workforce and institutional capacity exchange	Help countries translate electrification pathways into occupation-level skills needs, institutional capacity gaps, training partnerships, qualification standards and just-transition measures.	ISGAN WGs3+7, UNIDO, IRENA/ILO-type partners, education ministries, employers, utilities, unions.

CEM opportunity

Launch a portfolio of CEM17 actions within workstreams that helps countries do three things. **First - plan new demand before it appears; Second - use existing grids better; Third – scale flexibility as a reliable system resource.** Support this through 2–3 country Action Plans, targeted clinics, practical templates and a concrete actions in 2027 workplans.

Contents of this report

- **Introduction: Why Strategic electrification? Why now?**
 - Electrification as a whole-system opportunity for energy security, affordability and reliability.
- **1: Plan and shape rising electricity demand**
 - Anticipate where and when new demand will emerge - and use efficiency and flexibility to shape it before costs are locked in.
- **2: Assure electrification affordability through least-cost system design**
 - Reduce total system costs, protect consumers and compare infrastructure, efficiency and flexibility on equal terms.
- **3: Modernize infrastructure, increase system utilization and unlock flexibility**
 - Build grids faster, use existing assets better and make flexibility a dependable system resource.
- **4: Manage fuel, physical and cyber risks in electrified systems**
 - Prepare for the changing energy-security risks of increasingly electricity-dependent economies.
- **5: Build the workforce and institutions to deliver**
 - Ensure the skills, regulatory capacity and institutions needed to turn ambition into implementation.
- **Strategic Electrification: From report to implementation**
 - Practical opportunities for CEM cooperation, country action and 2027 delivery.
- **Annexes**

Textbox key

**Blue textbox:
Strategic insight**

Strategic insight:
The “so what” that changes how the reader thinks

**Grey textbox:
Implementation test**

Implementation test:
A practical diagnostic question governments/CEM can use

**Green textbox:
Transferable lesson**

Transferable lesson:
The key takeaway from case/example slides

**Orange textbox:
CEM Opportunity**

CEM opportunity:
A concrete cooperation opportunity

Strategic electrification can strengthen energy security when it is planned as a *system*

35%

IRENA global electrification target for end-use sectors by 2035, with electricity rising from roughly 23% today.

≥2x

Grid investment needs to roughly double to support electrification and renewables integration in IRENA's TAFF framing.

1100 TWh/yr

Average annual global electricity-demand growth expected through 2030 in IEA Electricity 2026.

3x by 2030

Approximate increase in daily flexibility needs versus 2019 in IRENA's decarbonization scenario.

Strategic insight

Electrification strengthens energy security only when the system around it is well planned, modern and capable. Clean power, grids, flexible demand, efficiency, markets, finance, risk management and workforce capacity have to scale together – otherwise countries risk adding new bottleneck risks in electricity infrastructure and institutions to ongoing fossil-fuel risks.

01

Plan and shape rising electricity demand

Plan demand before it materializes: where it appears, when it peaks, how flexible it is and what systems are needed to serve it.



Electricity demand is becoming more strategic and less predictable

The central issue is not only demand growth. It is new demand appearing at specific locations and hours, with different flexibility potential and infrastructure implications.

+1100 TWh/yr

Average annual global electricity-demand growth expected through 2030 — versus about 700 TWh/yr in 2015–2025.

49%

Share of additional global electricity demand to 2030 expected from buildings, including cooling, heat pumps and data centers.

~945 TWh

Global data-center electricity consumption projected by 2030 in the IEA Energy and AI Base Case.

6.4%/yr

Average electricity-demand growth expected for India through 2030, with cooling contributing over 20% of growth.

New demand drivers

- EV charging, heat pumps and cooling loads change peak shapes.
- Data centers and industrial electrification create large, concentrated connection requests.
- Hydrogen and Power-to-X can either increase demand or provide flexibility depending on design.

Planning challenge

- Annual demand forecasts cannot reveal substation, feeder or transmission constraints.
- Private investment timelines can move faster than grid planning, permitting and reinforcement.
- Social acceptance risk rises when infrastructure is planned after demand appears.
- Demand is changing rapidly, requiring frequent updating and incorporating.

Strategic opportunity

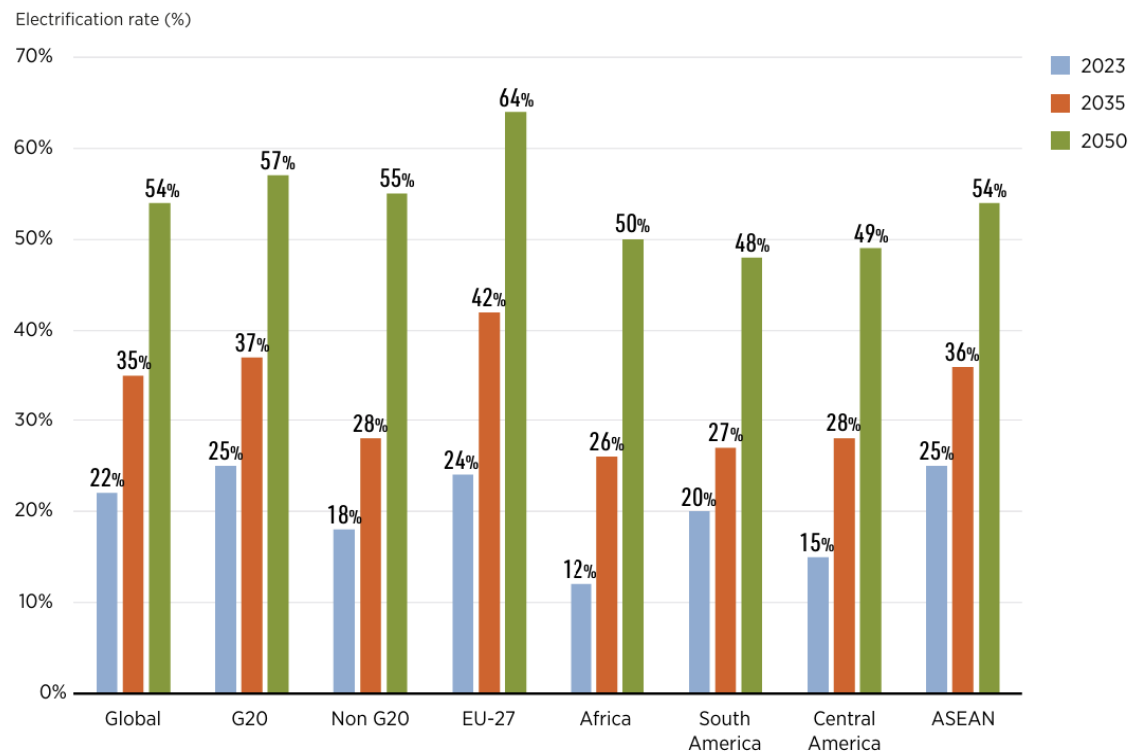
New demand can either become a grid bottleneck or a flexible system resource. Countries that identify where demand will appear, shape avoidable load, and bring flexible demand into planning can reduce peak-driven investment, improve connection decisions and make electrification more affordable.

Implementation test

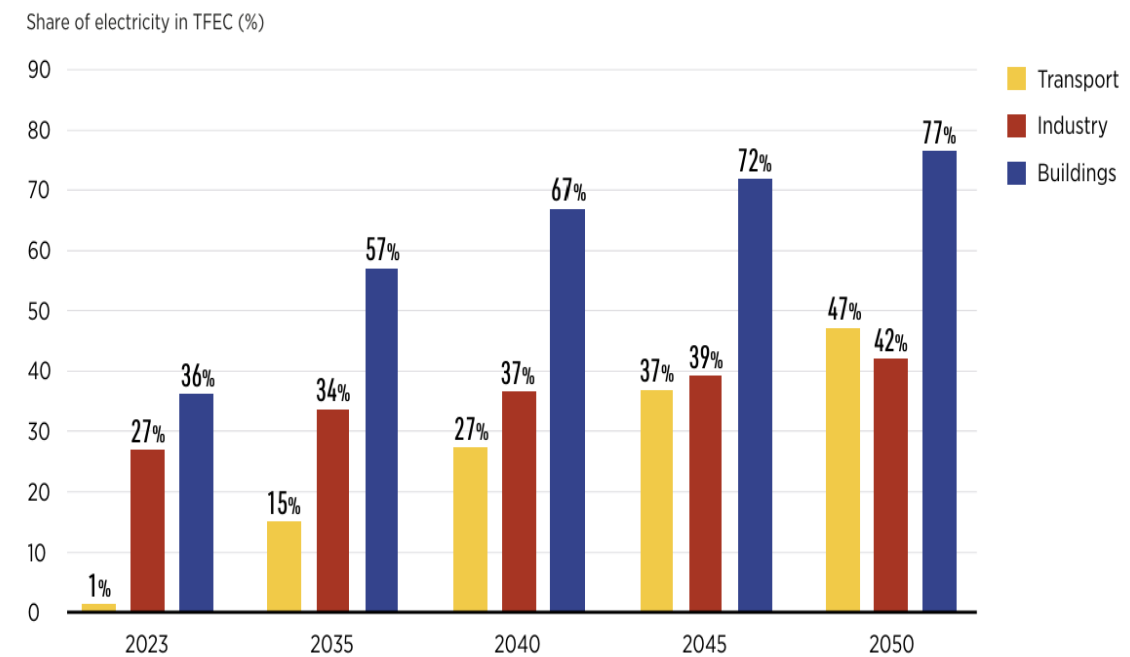
How can countries turn demand uncertainty into actionable planning, connection, market and investment decisions?

Evolution of global electrification rate in the revised 1.5°C Scenario, by sector (right), by region (left), 2023–2050

Strategic electrification will not follow one global template: sectoral demand, development needs, resource endowments and energy-access priorities will shape different pathways.



Source: (IRENA, Forthcoming a).
Notes: ASEAN = the Association of Southeast Asian Nations; EU = European Union; G20 = the Group of 20, excluding the African Union;
Total final energy consumption excludes international marine and aviation bunkers, except at global level.



Source: (IRENA, Forthcoming a).
Notes: TFEC = total final energy consumption; Maritime and aviation bunkers are included in the total final energy consumption at the global level.

Strategic insight

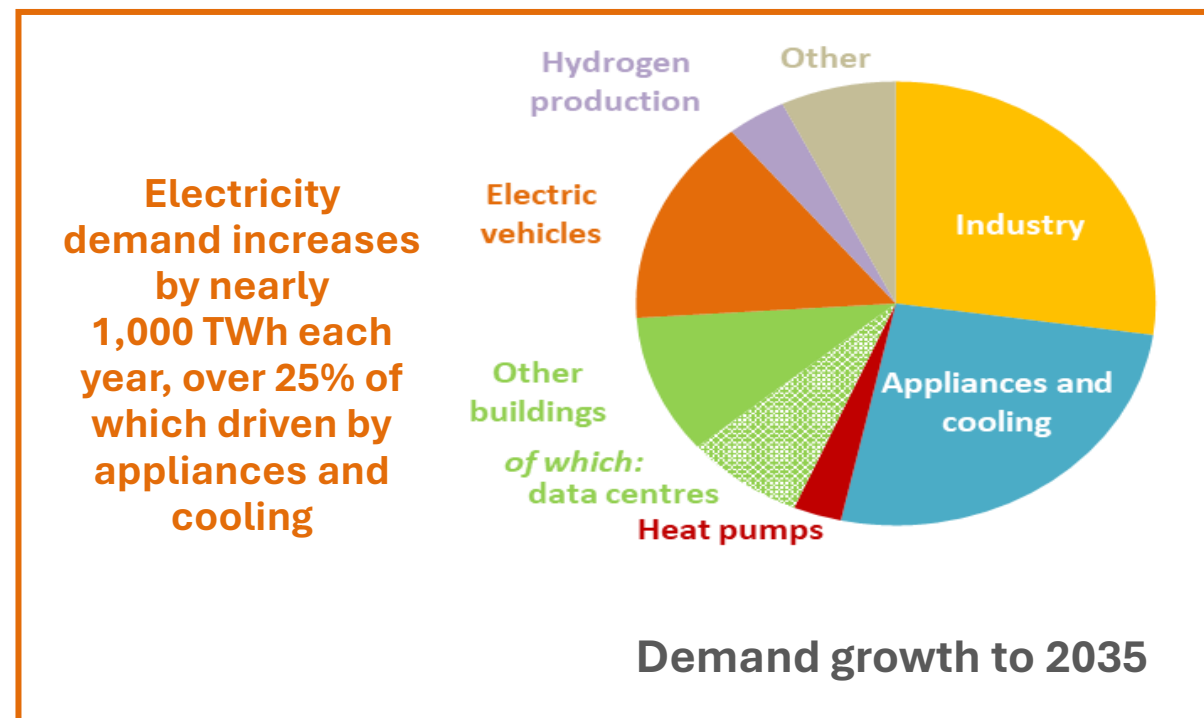
Electrification pathways will differ between regions, reflecting disparities in the structures of their respective economies and patterns of energy demand, as well as in their development, resource endowments and level of energy access.

Electricity demand growth by end-use from 2024 to 2035 in the IEA stated policies scenario

Buildings, appliances and cooling will account for a large share of future electricity demand growth. Product standards and building policy can shape that demand before it reaches the grid — reducing future peaks, system costs and infrastructure needs

Appliance policy is not a side issue. It is one of the tools that changes the amount of power the system must serve.

Appliance policies are among the lowest-cost tools to manage future electricity demand growth before it occurs.



Strategic insight

Appliance and cooling policy shapes the future power system. Improving efficiency today can reduce future peaks, consumer bills and infrastructure needs before those costs are locked in

Demand planning: The practical barrier is coordination, not just forecasting

Demand planning becomes useful when it connects the institutions, data and decisions that determine whether future load becomes a bottleneck or a manageable system resource.

Barrier	Why it blocks implementation	Planning response
Fragmented ownership	Demand planning depends on ministries, regulators, utilities, DSOs, cities and large users, but no single actor may own the full picture.	Create a shared planning process with named owners, data responsibilities and update cycles.
Weak demand visibility	End-use stock, distribution-level load, network constraints and weather-sensitive profiles are often missing or held separately.	Build minimum viable demand datasets, using proxies where local data is incomplete.
Speculative large loads	Data centers, industry, hydrogen and charging developers may enter queues before timing, utilization and flexibility are credible.	Set large-load transparency requirements before connection requests become planning signals.
Efficiency treated separately	Appliance, cooling and building policies are often outside power planning, so forecasts can overbuild for avoidable demand.	Include minimum energy performance standards (MEPS), labels, efficient cooling and stock-turnover assumptions in demand scenarios.
Flexibility undervalued	Flexible demand is often modelled crudely or excluded because availability, consumer behavior and rebound effects are uncertain.	Quantify flexible load by location, duration, reliability, automation and market-access conditions.
Social acceptance too late	Infrastructure choices become harder to deliver when communities and local authorities are engaged after pathways are locked in.	Use participatory planning early enough to shape siting, sequencing and investment choices.

Strategic insight

Demand planning is not a forecasting exercise alone; it is a coordination exercise. Its value is in turning scattered information on loads, locations, efficiency and flexibility into decisions before infrastructure costs are locked in.

Demand planning: Emerging best practices

A demand plan does not need perfect data to be useful; it needs enough detail to guide real choices on grids, generation, flexibility, tariffs, finance and delivery.

Planning layer	Question it answers	What to include
1. End-use adoption and efficiency	What new loads are being adopted?	EVs, cooling, appliances, heat pumps, industrial processes, hydrogen and data centers; include efficiency standards and stock turnover.
2. Load profiles and weather	When does demand appear?	Hourly and seasonal profiles under different weather conditions, including heatwaves, cooling demand, agricultural pumping and charging behavior.
3. Location and grid constraints	Where does demand connect?	Feeders, substations, transmission nodes, connection queues, local permitting constraints and distribution-level visibility.
4. Flexibility potential	What demand can shift, reduce or respond?	Flexible portions of load, activation windows, automation, consumer participation, rebound effects and market access conditions.
5. Delivery and investment pathway	How does the plan get implemented?	Grid investment, generation procurement, tariffs, finance, social acceptance, named owners and update cycles.

Implementation test

Can the demand plan guide real decisions on where to build, where to reinforce, where to procure flexibility, and where efficiency can avoid unnecessary system costs?

Demand planning depends on coordination across the system

No single actor sees the whole demand picture, so strategic electrification needs a planning process that turns distributed information into shared decisions.

Actor	What they hold	Why they need to be in the process
National energy planners	Scenarios, targets, generation pathways and policy assumptions.	Set the overall direction but need more granular demand and delivery inputs.
Distribution operators	Feeder/substation constraints, local load growth, connection requests and hosting capacity.	Future demand often lands first on distribution systems; without DSO data, plans miss local bottlenecks.
Transmission/system operators	System adequacy, congestion, flexibility needs, interconnection and operational constraints.	Translate demand growth into generation, grid, balancing and resilience requirements.
Regulators and permitting bodies	Investment approvals, tariff rules, connection rules, market access and permitting timelines.	Decide whether plans can be implemented, financed and approved at the required pace.
Cities, local authorities and communities	Land use, transport plans, building stock, local priorities and social acceptance.	Shape where demand emerges and whether the required infrastructure can be delivered locally.
Large users and flexibility providers	Timing, location, utilization and flexibility of EV charging, data centers, industry, hydrogen and DERs/VPPs.	Turn uncertain demand into actionable planning signals and potential system resources.
Finance and delivery institutions	Project pipelines, risk treatment, procurement needs and investment constraints.	Help ensure plans become fundable delivery pathways rather than scenario exercises.

Source: Adapted from IRENA participatory planning guidance and synthesized with 21CPP member inputs on demand growth, flexibility, large-load transparency and planning-to-investment

Implementation test

Does the planning process bring the right actors and data together early enough to agree where demand will appear, what can be avoided or shifted, what infrastructure is needed, who owns delivery, and how the plan will be updated?

Demand planning: Incorporating growth and demand flexibility

The strongest demand plans do not just forecast future load; they test how policy, efficiency, smart charging and flexible products can change the load the system must serve.

45%

Appliances' share of electricity demand in buildings.

30-40%

Efficiency improvement needed in appliances to support doubling global energy-intensity improvement by 2030.

2–3x

Inefficient appliances can consume two to three times as much energy as efficient models.

10–15 years

Typical lifetime of inefficient appliance stock that can lock in avoidable demand.

Anticipate demand

Build bottom-up demand profiles for EVs, cooling, appliances, industry, hydrogen and data centers. Test adoption pathways, different weather conditions, large-load timelines and grid locations. The output should feed directly into grid planning, procurement and investment decisions.

Shape demand before it locks in

Use MEPS, labels, efficient cooling, public procurement, incentives, smart charging and demand-response-ready products to reduce avoidable demand and peaks before generation and network capacity is built around them.

Strategic insight

Demand forecasts should not treat demand as fixed. They should test the choices that shape it: strong or weak appliance standards, unmanaged or smart charging, static or dynamic tariffs, and low or high transparency from large loads.

Case: Sweden shows why demand scenarios must be linked to infrastructure

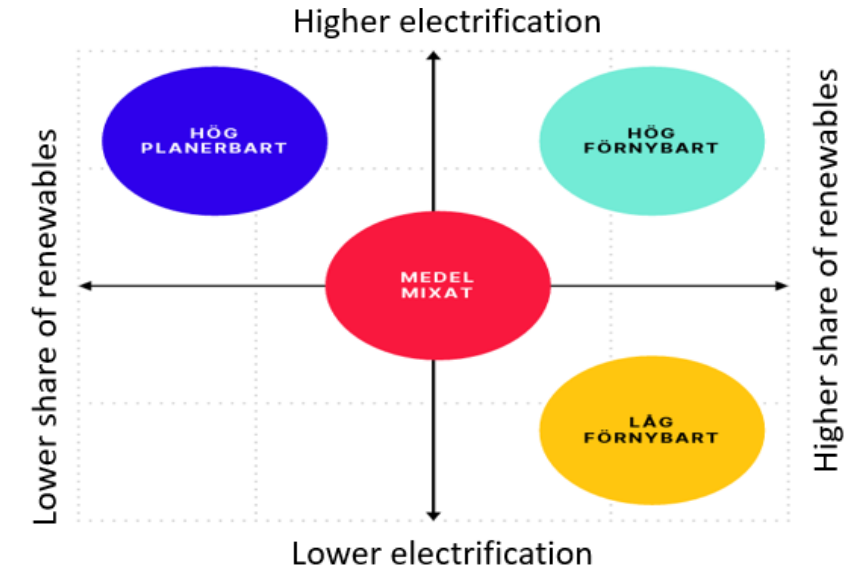
Sweden's example shows why demand scenarios need to be tested alongside generation, grids and flexibility, so infrastructure choices remain robust across plausible futures.

Problem

- Sweden faces high uncertainty around electrification, industry, hydrogen, renewable shares and generation mix.
- A single central forecast would hide the range of possible infrastructure pathways.

Approach

- The Swedish TSO's long-term market analysis tests demand and generation futures together.
- Scenario axes include higher/lower electrification and higher/lower renewable shares.



- **Swedish TSO's Long-Term Market Analysis 2026** shows why demand scenarios must be linked to generation, grids and flexibility. The lesson is not that countries need perfect forecasts; it is that they need planning frameworks robust enough to handle different electrification, industrial demand and generation pathways.
- **Four scenarios:** The scenarios in the long-term market analysis relate to each other based on two scenario axes: electrification rate and share of renewable electricity production.

Figure Source: Sweden's el. system decarbonization scenarios. Ref. <https://www.svk.se/om-oss/rapporter-och-remissvar/langsiktig-marknadsanalys/>

Hög plannerbart=high plannable, medel mixat=medium mixed, låg förnybart=low renewables, hög förnybart=high renewables

Transferable lesson

Robust planning is not about predicting one future correctly. It is about identifying decisions that hold across plausible futures — and knowing which choices should be staged until uncertainty narrows.

Address data gaps and participation challenges

Countries can start with workable data and improve it over time, provided assumptions are transparent, updated regularly and tested with the actors who will deliver or be affected by the plan.

Example / method	What the member input shows	What countries can adapt
India: bottom-up demand profiles despite data gaps	Planners can represent EVs, cooling and demand-side flexibility using proxy profiles, early-adopter evidence and scenario ranges where domestic data is incomplete.	Build “minimum viable” demand profiles; test unmanaged vs managed demand; update assumptions as local data improves.
PAC scenario: participation as implementation asset	Civil-society co-creation, open modelling and published datasets can improve legitimacy, accountability and social acceptance of infrastructure choices.	Bring DSOs, regulators, cities, large users, communities and civil society into planning before choices are locked in.
Cross-cutting lesson	Demand planning needs enough data and enough legitimacy to guide real decisions on grids, procurement, tariffs, flexibility and siting.	Make assumptions visible; model weather years and flexible load explicitly; resource participation throughout the process, not only at the end.

Source: Adapted from LTES/IRENA inputs on demand profiles, India case studies, the PAC scenario and participatory strategic energy planning; synthesized with 21CPP demand-planning framing.

Transferable lesson

Start with workable data, make assumptions transparent, and build legitimacy before infrastructure choices harden.

Adapting from demand-planning examples

The examples point to a common lesson: demand uncertainty should not delay action. Countries can use scenarios, proxy data and participatory planning to make better decisions before infrastructure choices harden.

Example	What it shows	What others can adapt
Sweden: scenario-based planning	Long-term planning can test different futures for electrification, industrial demand, hydrogen, renewables, grids and flexibility rather than relying on one central forecast.	Use scenario axes that reflect real domestic uncertainties; identify investments that are robust across futures; stage decisions where uncertainty remains high.
India: demand profiles despite data gaps	Planners can start with credible proxy data and early-adopter evidence to represent EVs, cooling and demand-side flexibility while local datasets improve.	Build minimum viable demand profiles; model unmanaged vs. managed demand; update assumptions as real data becomes available.
PAC scenario: participation as delivery asset	Open modelling, civil-society input and published assumptions can improve legitimacy, accountability and social acceptance.	Bring DSOs, regulators, cities, large users, communities and civil society into planning early enough to affect choices.
CEM comparison opportunity	Countries face similar choices about uncertainty, data quality, participation and timing of investment.	Compare approaches to scenario design, proxy data, stakeholder participation, large-load transparency, anticipatory investment and flexible/non-firm connections.
Low-emission product-market signals.	Green procurement, buyer commitments and emissions-performance requirements can make future industrial demand more credible.	Treat product-market signals as demand-planning inputs where they affect future electricity load, not only as industrial-policy tools.

Strategic insight

The aim is not perfect demand forecasting. It is better decision-making under uncertainty: making future load visible, testing flexibility and efficiency options, and building enough legitimacy for infrastructure choices to move.

Priority action and CEM collaboration opportunities

CEM can help countries move from demand uncertainty to practical planning methods: minimum viable demand profiles, large-load transparency, efficient cooling, flexible demand modelling and participatory planning.

Action	What this means in practice	CEM cooperation opportunity
Build bottom-up demand profiles	Test demand by end-use, location, timing, weather conditions and flexibility potential; use DSO data where available and proxies where not. Map industrial electrification opportunities by process, technology, load profile and flexibility potential.	Develop a “minimum viable demand profile” checklist with LTES/GCEP, SEAD and ISGAN inputs.
Create large-load transparency	Set expectations for data centers, industry, hydrogen, EV charging and other large loads to share timing, size, location, utilization, backup and flexibility.	Compare approaches to large-load disclosure, connection transparency and queue discipline.
Integrate efficiency and cooling	Include MEPS, labels, efficient cooling, stock turnover and appliance-policy scenarios in demand forecasts, IRPs and grid plans.	Use SEAD expertise to develop practical toolkits and clinics on efficient cooling and appliance policy.
Value flexible demand	Model flexible load as a planning resource, with realistic assumptions on availability, duration, location, rebound, automation and consumer safeguards.	Share modelling and validation methods across planners, regulators and system operators.
Use participation to improve delivery	Engage DSOs, regulators, cities, permitting bodies, large users, communities and civil society before pathways are locked in.	Peer exchange on participatory planning, social acceptance and linking demand plans to grid/permitting decisions.
Run regulatory-readiness checks	Assess whether regulatory mandates, governance arrangements, skills, capacity and processes are ready for demand growth, flexibility, anticipatory investment and consumer protection.	Regulatory Health Check clinic, drawing on ERAD expertise and linked to country Action Plans.

CEM opportunity

Demand Growth Planning Exchange — Peer to Peer Learning for large-load transparency, efficient cooling, flexible demand modelling and inclusive processes.

02

Assure electrification affordability through least-cost system design

Make electrification affordable by reducing total system costs, avoiding inefficient peaks, protecting consumers and strengthening business confidence.



Affordable electrification depends on system design, not just electricity prices

Affordable electrification depends on managing bills, business competitiveness and total system costs together. Efficiency, flexible demand, tariff design, consumer protection, non-wire alternatives and bankable investment determine whether electrification is affordable and trusted.

Bills, trust and competitiveness

- Efficient products, targeted support and financing shape whether households can afford to adopt and use electric technologies.
- Lifetime costs matter: low purchase prices can lock consumers into high operating costs.
- Simple, trusted propositions are essential for participation in flexibility, smart charging and dynamic tariffs.
- Industrial electrification depends on reliable, affordable power and credible connection timelines.

Total system costs

- Unmanaged peaks, poorly sequenced demand and default reinforcement can raise costs for all users.
- Efficient cooling, appliance standards and flexible demand can avoid or defer network and generation investment.
- Least-cost planning should compare wires, non-wire alternatives, efficiency, storage and demand response on a credible basis.

Markets and investment

- Tariffs and market rules determine whether flexible demand can reduce costs or remains invisible.
- Metering, data access, interoperability and measurement/verification make flexibility usable and trusted.
- Clear procurement routes, revenue models and de-risking can mobilise storage, flexibility and digital infrastructure.

Strategic insight

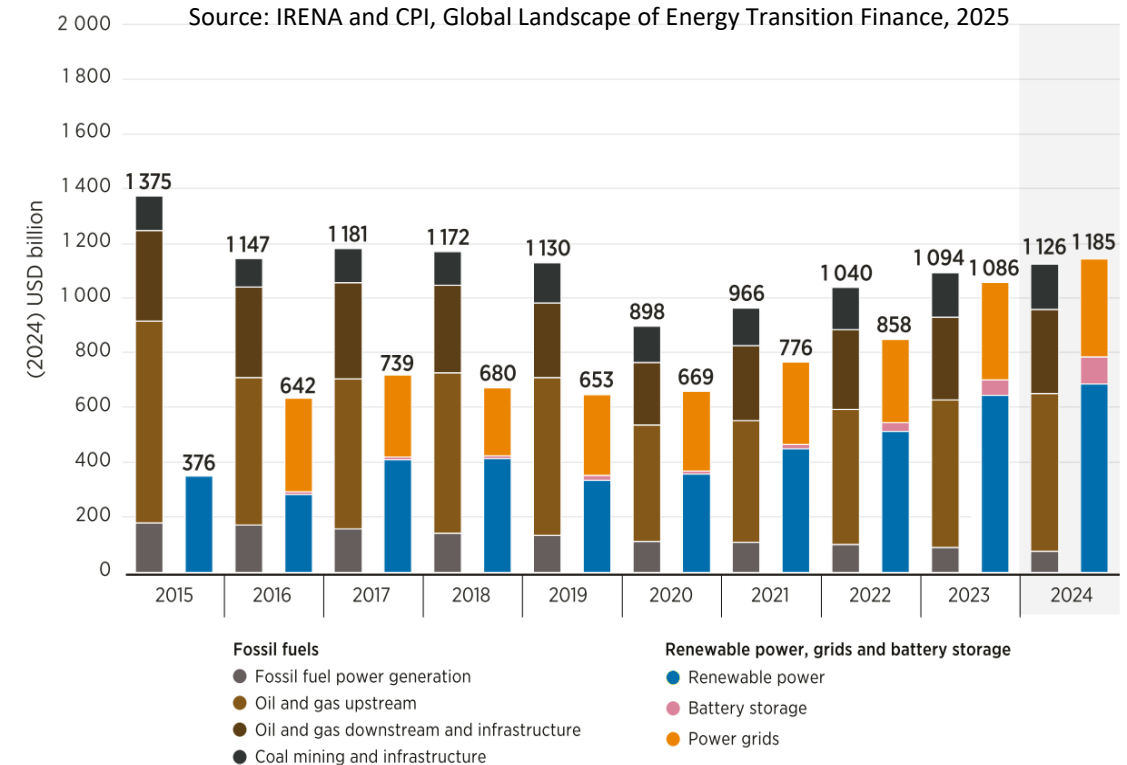
Affordability is not achieved by hiding costs. It is achieved by reducing avoidable costs, financing necessary investment efficiently, and designing tariffs and markets that keep consumers engaged rather than exposed.

Affordability depends on how the investment wave is planned, financed and used

For the past 10 years, global spending on clean energy has been higher than investments in fossil fuels. But strategic electrification still requires major additional capital for grids, storage, flexibility, digital systems and clean generation. The affordability question is therefore not whether investment is needed, but how countries reduce unnecessary cost, recover unavoidable cost fairly, and lower financing risk.

- **Plan investment around total system cost:** Compare generation, grid reinforcement, storage, flexibility, efficiency and non-wire alternatives on a common basis.
- **Avoid peak-driven overbuild:** Efficient products, flexible demand and better utilization of existing assets can reduce unnecessary network and generation costs.
- **Reduce financing costs:** Credible plans, procurement routes, revenue models and de-risking instruments can lower the cost of capital.
- **Protect consumers and competitiveness:** Cost recovery needs to maintain trust, support vulnerable consumers and keep electricity affordable for industry.

Annual investments in renewables, grids and storage versus fossil fuels, 2015-2024



Strategic insight

Countries can end up paying for electrification twice: first by allowing unmanaged demand to create avoidable peaks, and then by financing infrastructure to serve them. Least-cost electrification means valuing efficiency, flexibility and non-wire alternatives before those costs are locked into bills.

Affordability depends on choices made before costs reach bills

The same electrification pathway can produce very different affordability outcomes depending on whether countries recognize efficient products, flexible demand, non-wire alternatives and bankable investment in planning, regulation and markets.

Five shifts for least-cost strategic electrification

1. **From upfront cost to lifetime cost:** Consumers may choose cheaper products that are expensive to run unless standards, labels, financing, procurement and targeted support make efficient options accessible.
2. **From default reinforcement to least-cost options:** Grid investment needs to grow – but regulators should compare reinforcement with efficiency, flexible connections, storage, demand response and other non-wire alternatives.
3. **From invisible flexibility to valued system resource:** DERs, storage and flexible demand can reduce costs significantly – but only if rules, thresholds, metering, data access and measurement/verification allow them to participate.
4. **From complex tariffs to trusted participation:** Dynamic and cost-reflective price signals can lower system costs, but they need simple consumer propositions, appropriate safeguards and opt-outs.
5. **From pilots to bankable models:** Flexibility, storage and digital infrastructure need clear procurement routes, bankable revenue models and de-risking tools to move from pilots to scale – with proven approaches translated into policy and grid practice.

Strategic insight

The biggest affordability choices are made before costs reach bills: which products consumers buy, whether demand can flex, whether non-wire alternatives are valued, and whether investment is sequenced around real system need.

Least-cost electrification means comparing all options on equal terms

Affordability improves when regulators and planners assess grid reinforcement, flexible connections, non-wire alternatives, efficiency, storage and demand response *as part of one system-cost calculation* — not as separate policy silos.

Compare wires and non-wires on equal terms

Use common technical and economic criteria to compare reinforcement, flexible connections, efficiency, storage and demand response.

Probabilistic planning can avoid overbuilding for rare peaks while maintaining reliability.

Make demand-side resources usable

Tariffs, markets and aggregation can turn flexible demand, DERs and VPPs into cost-saving resources.

Efficient products, MEPS, labels and procurement can prevent avoidable demand and high operating costs from being locked in.

Make participation trusted and financeable

Consumer participation needs consent, transparency, opt-outs, data protection, targeted support and fair compensation.

Flexibility, storage and digital infrastructure also need clear procurement routes, revenue models, data access and interoperability.

Implementation test

Can regulators approve the cheapest reliable option across wires, flexible connections, efficiency measures and flexibility contracts — or do rules still default to reinforcement even when lower-cost alternatives exist?

Case: UK distribution flexibility markets show how flexible demand can reduce system costs

UK Power Networks' experience illustrates a broader point: flexibility only delivers affordability benefits when system operators can procure it at specific locations and times, aggregators can participate, and consumers have propositions they trust.

>1 GW

Flexibility contracted by UK Power Networks by 2023, after first procurement in 2017.

200+

Daily auctions held in 2024/25 through a day-ahead flexibility market.

13 GWh

Flexibility delivered in 2024/25, a 68% increase on the previous year.

£205m

Reported savings since April 2023 through more efficient use of distribution capacity.

What made it work

- **Locational need was visible:** The DSO could identify where flexibility could help manage distribution constraints
- **Products were contractable:** Day-ahead and longer-term procurement created routes for aggregators and distributed assets
- **Consumer participation was usable:** Demand turn-up and other propositions rewarded consumers for shifting demand when it helped the system.
- **Flexibility complemented reinforcement:** Procurement gave the DSO an option between immediate network build and targeted local flexibility.

What others can adapt

- Define local flexibility products clearly enough for aggregators and consumers to participate.
- Compare flexibility and reinforcement using transparent cost, reliability and deliverability criteria.
- Put measurement, verification, settlement and consumer safeguards in place early.
- Move flexibility from pilots into standard distribution planning and procurement practice.

Transferable lesson

Flexibility reduces costs only when it is visible, contractable and trusted — by system operators, aggregators and consumers.

Case: Planning methods determine whether least-cost options are visible

Italy and Portugal show that the question is not only which technologies are available. It is whether planning and regulation allow flexibility and non-wire alternatives to be compared fairly with conventional reinforcement.

Italy: Risk-based planning reveals usable capacity

A southern Italy distribution study assessed 43 primary substations and around 400 MV feeders to 2050 under high EV and PV uptake.

Deterministic worst-case planning found 43% of MV lines requiring upgrades by 2050, with 36% in the first decade. A probabilistic approach reduced these to 31% and 17%, with around **30% CAPEX reduction** while maintaining reliability.

Portugal: Flexibility as a regulated non-wire alternative

E-REDES used probabilistic network dimensioning in its 2026–2030 distribution investment plan. Conventional reinforcement was compared with flexibility for seven projects worth around EUR 27 million, translating constraints into required flexible power, activation periods and network locations.

What this shows

- Worst-case deterministic planning can overstate permanent reinforcement needs.
- Risk-based methods make flexibility visible for rare but critical conditions.
- Flexibility can only substitute for reinforcement where observability, reliability criteria, procurement and verification are strong enough.

What regulators need

- Transparent reliability standards and cost-benefit methods.
- Low Voltage (LV) observability and network data
- A way to value avoided or deferred reinforcement
- Contractable flexibility that can be relied on in planning.

Transferable lesson

Least-cost electrification depends on planning methods. If regulators cannot compare reinforcement, flexibility and non-wire alternatives on equal terms, systems will tend to overbuild and pass avoidable costs to consumers.

Case: Energy Efficient products reduce bills *before* demand reaches the grid

Product policy is part of power-system planning: every inefficient or inflexible appliance sold today locks in future demand the grid must serve.

Consumer affordability

- Efficient appliances reduce operating costs and protect households from high bills.
- Labels, lifetime-cost information and targeted finance help consumers choose products that are cheaper to own, not just cheaper to buy.
- Low-income households may need targeted replacement, rebates or concessional finance so efficient electric equipment is accessible.

System affordability

- Efficient appliances reduce aggregate demand and peak load.
- Higher-efficiency cooling can avoid or defer investment in generation, networks and flexibility capacity.
- Inefficient equipment can lock in avoidable demand for years, making electrification more expensive than it needs to be.

Policy & market tools

- MEPS, labels, public procurement, rebates and compliance systems can shift markets.
- Regional harmonization can reduce implementation costs and help manufacturers scale efficient products.
- Demand-response-ready products can combine efficiency with flexibility, so appliances reduce demand and respond when the grid needs it.

Lessons from Jakarta, Indonesia

SEAD's example of annual electricity consumption for cooling a small apartment in Jakarta makes the point concrete: thermostat settings, fans and efficient ACs jointly determine consumer bills and peak pressure.

Lessons from the United States

Long-standing appliance standards can reduce energy use while preserving consumer service and affordability when standards, labels, market transformation and compliance evolve together.

Transferable lesson

Efficient products are demand-side infrastructure. They protect consumers, reduce avoidable system costs and make electrification easier to serve affordably.

CEM can help countries make affordability a system-design agenda

The practical cooperation opportunity is to help countries compare and combine efficient products, flexible demand, non-wire alternatives, consumer safeguards and investment de-risking — so affordability is built into system design before costs reach bills.

- 1. Put flexibility and non-wire alternatives into planning:** Make flexibility, efficient end-use policy, storage and non-wire alternatives standard options in network planning and investment approval.
 - **CEM role:** Compare regulator approaches to flexibility valuation, reserve prices, non-wire alternatives and investment approval.
- 2. Design tariffs and incentives that consumers can trust:** Reward flexible behavior while avoiding excessive complexity, unfair cost shifts or risks for vulnerable consumers.
 - **CEM role:** Peer exchange on dynamic pricing, demand turn-up, simple consumer propositions, opt-outs and safeguards.
- 3. Treat efficient products as affordability infrastructure:** Use standards, labels, incentives, procurement and compliance systems to reduce lifetime costs and avoid inefficient appliance stock.
 - **CEM role:** Use SEAD to share policy packages, testing systems, labelling, compliance and regional harmonization lessons.
- 4. Fund the data layer for least-cost choices:** Smart metering, LV visibility, interoperable protocols and secure data access are prerequisites for credible flexibility markets and least-cost planning.
 - **CEM role:** Develop a practical data and interoperability checklist for flexibility and non-wire alternatives.
- 5. De-risk flexibility, storage and digital infrastructure:** Use pilots, procurement frameworks, bankable contracts, revenue certainty and concessional finance where business models are immature.
 - **CEM role:** Connect GPFM, ISGAN, regulators and finance actors around bankable flexibility and digitalization pilots.

CEM opportunity

Launch an Affordability and Flexible Demand Peer Learning Stream focused on flexibility valuation, trusted tariffs, efficient products, data readiness and bankable non-wire alternatives.

03

Modernize infrastructure, increase system utilization, and unlock flexibility

Pursue Smart Electrification: Build faster, connect faster and use existing assets better. Combining regulatory reform, permitting, GETs/ATTs, flexibility, digitalization, AI and investable delivery plans.



Load growth is driving the need to build grids faster – and use existing grids better

Grid buildout is essential – but buildout alone will not move fast enough. Countries need to unlock usable capacity now while planning, permitting and financing the infrastructure that still needs to be built.

>2,500 GW

Renewable, storage and large-load projects reportedly stalled in grid queues worldwide.

5–15 years

Typical planning, permitting and completion timeline for new grid infrastructure.

1,200–1,600 GW

Hosting capacity that could be unlocked via non-firm connections and grid technologies/upgrades.

450–700 GW

Potential unlocked through GETs and upgrades, including dynamic ratings, power-flow control and reconductoring.

Use existing assets better

- Publish hosting-capacity and congestion information.
- Deploy GETs/ATTs, dynamic line ratings, advanced conductors and topology optimization.
- Make flexible/non-firm connections a standard product where suitable.

Build what is still needed

- Accelerate permitting, siting and long-term transmission and distribution planning.
- Align generation, storage, load and grid readiness.
- Avoid underbuilding where flexibility cannot substitute for durable capacity.

Make delivery investable

- Translate plans into milestones, pipelines, procurement routes and finance instruments.
- Bring finance ministries, MDBs/DFIs and private finance into planning early.
- Use country Action Plans to test sequencing and ownership.

Strategic insight

The near-term grid challenge is not only scarcity of infrastructure; it is scarcity of usable capacity. Hosting maps, flexible connections, GETs/ATTs and demand flexibility can turn hidden capacity into a delivery resource while new build catches up.

Grid modernization works when reforms, technologies and finance are sequenced together

The challenge is not choosing between grid buildout, optimization, flexibility, digitalization and finance. It is including them as a *portfolio of delivery options*, so countries can connect new demand and clean power faster while keeping costs and risks under control.

1. **Reform:** Modernize connection queues and approvals, clarify investment treatment, align connection rules, simplify data access and allow alternatives to reinforcement to be assessed
2. **Optimize:** Use hosting-capacity maps, calculated capacity, GETs/ATTs, dynamic ratings, advanced conductors and topology optimization to increase usable capacity.
3. **Flex:** Integrate storage, smart charging, flexible appliances, demand response, DERs and VPPs into planning, connection agreements, markets and operations.
4. **Digitize:** Build secure data foundations, including data governance, quality and interoperability, digital permitting queues and grid-grade AI decision-support pathways.
5. **Build and finance:** Turn plans into project pipelines, procurement routes, revenue models, risk tools and financeable milestones.

Implementation test

Can the system integrate new build, better utilization, flexibility, digital tools and finance measures as one delivery pathway — or are decisions still being made in separate silos?

A grid-utilization playbook can turn latent capacity into usable capacity

A practical grid-utilization agenda combines better visibility, calculated capacity, flexible access, non-wire alternatives and stronger data foundations.

Five practical levers

1. **Hosting-capacity maps:** Publish locational capacity, congestion and queue information at useful granularity, with confidence levels and update frequency.
2. **Calculated capacity:** Replace generic screening thresholds with locational assessment where data allow, so capacity reflects actual feeder and substation conditions.
3. **Flexible connections:** Offer non-firm or flexible access with transparent curtailment rules, communication requirements, compensation and user rights.
4. **Non-wire alternatives:** Assess reinforcement, flexibility, GETs/ATTs and connection solutions using consistent technical, economic and reliability criteria.
5. **Data foundations:** Fund LV observability, interoperable asset data, secure access and common definitions for planners, operators, regulators and markets.

CEM opportunity

A grid-utilization peer-to-peer workshop could help countries compare hosting-capacity map design, flexible connection products, non-wire alternatives, regulatory treatment, data governance and operational safeguards and lead to practice adoption of leading practices.

Digitalization and AI should support grid decisions, not replace governance

The value of AI is not autonomy for its own sake. It is trusted, secure decision support that helps planners and operators see constraints earlier, test options faster and act with stronger safeguards.

A staged pathway for grid-grade digitalization and AI

- **Connect:** Establish asset identifiers, interoperability, secure data spaces and data-quality KPIs.
- **See:** Improve visibility of congestion, asset health, outages, restoration and distributed resources.
- **Predict:** Forecast load, renewables, congestion, asset failure and operational risk.
- **Decide:** Support operators with options for reconfiguration, flexibility activation, maintenance and targeted reinforcement.
- **Interact:** Use explainable interfaces only where outputs are evidence-grounded and auditable.
- **Act:** Move from advisory tools into operational use only when responsibilities are clear, safeguards are tested, decisions can be audited, and cyber risks are managed.

Implementation test

Can a digital or AI tool improve a real planning or operational decision — and can it be audited, explained, secured and safely overridden?

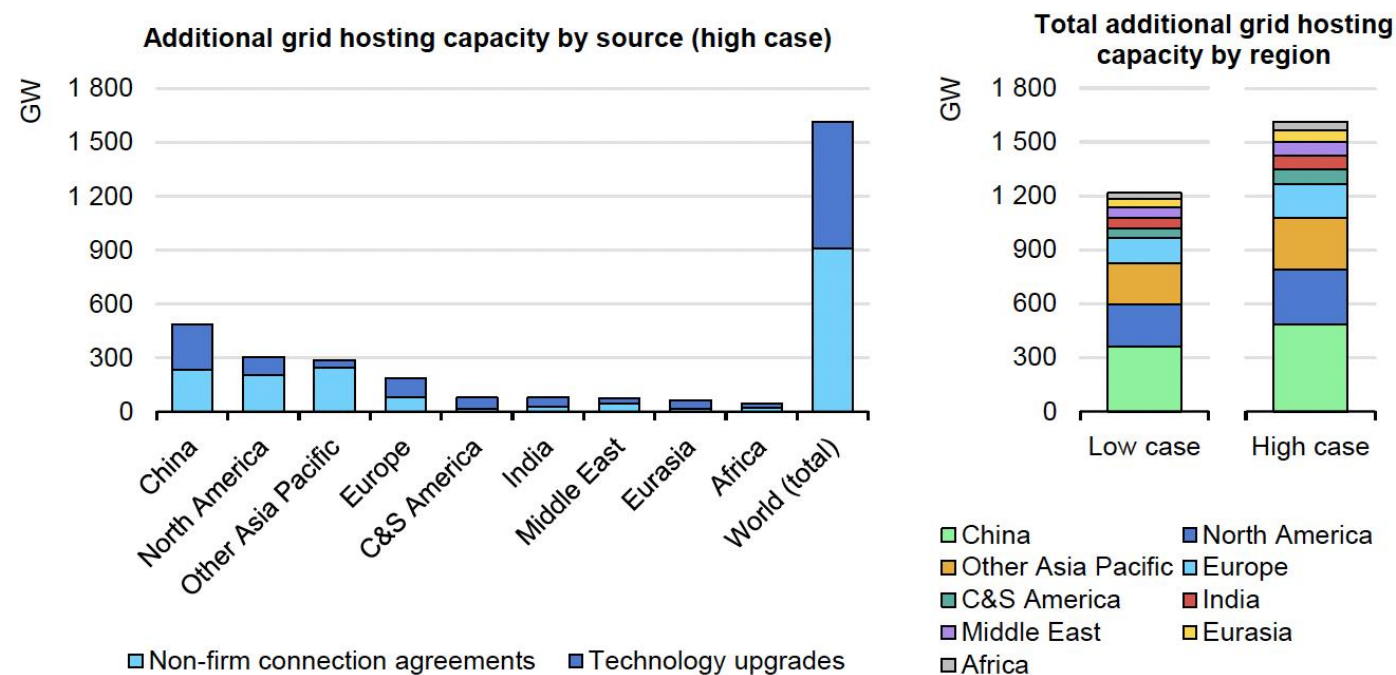
Non-firm connections and grid technologies can unlock capacity before new build arrives

Significant hosting capacity can be unlocked through non-firm connection agreements and technology upgrades. The policy challenge is to turn those options into standard, trusted products rather than isolated pilots.

Unlocking Capacity Actions

- Generic screening limits need to be replaced with locational capacity assessment where data allow.
- Non-firm and flexible connection rules need standard products, transparent curtailment terms and clear user rights.
- GETs/ATTs need regulatory treatment that rewards improved utilization, not only new build.
- Data systems need common asset IDs, interoperable formats and secure sharing arrangements.
- Flexible appliances, DERs, storage and VPPs need market access and interoperability rules.

Estimated grid hosting capacity that can be unlocked via non-firm connection agreements and technology upgrades by source (left), and by region (right), 2025



Source: IEA, Electricity 2026, <https://www.iea.org/reports/electricity-2026/grids>

IEA. CC BY 4.0.

Strategic insight

Demand flexibility is prepared before it is dispatched. Products must be efficient, controllable and interoperable; consumers need simple and trusted offers; and system operators need visibility, measurement and settlement before flexible demand can count as a reliable resource.

Case: Network-capacity maps turn engineering data into planning signals

The United States, Netherlands and Japan show different ways to make grid capacity more visible to developers, planners and regulators. The common point is that capacity information becomes more useful when it is regular, granular, comparable and linked to clear connection options.

United States

Utilities and state agencies publish hosting-capacity maps, with federal resources providing a national atlas of available map resources.

Lesson: Distributed-capacity information can become a public signal, not only an internal engineering tool.

Japan

Network operators publish available-capacity maps through a common national portal.

Lesson: Transparency can be coordinated across operators while preserving local engineering judgement.

Netherlands

A national capacity map combines congestion information with connection requests, with monthly queue updates.

Lesson: Queue transparency can improve application quality and planning discipline.

Transferable lesson

Capacity maps matter most when they are updated, granular enough to guide decisions, comparable across regions, and linked to flexible or non-firm connection products.

Case: Digital infrastructure works when it reduces friction in real decisions

Digital infrastructure is valuable when it solves concrete coordination problems: finding data, sharing data securely, aligning formats, reducing bespoke legal barriers and improving decisions.

UK Data Sharing Infrastructure

The UK example addresses data that is hard to locate, stored in incompatible formats, trapped in legacy systems or governed by bespoke legal agreements.

AI use-case progression

Across data hubs, inspection, weather and wildfire monitoring, PV nowcasting, cable-failure risk, operator support and governed control, the lesson is progression: data foundations first; autonomy later, if ever.

Implementation barriers

- Siloed SCADA, AMI, GIS*, asset and planning data.
- Unclear access rights and cybersecurity concerns.
- Inconsistent identifiers and data-quality standards.
- Revenue uncertainty for shared data infrastructure.

Policy actions

- Create data governance and access frameworks.
- Use digital permitting and queue data where useful.
- Define data-quality KPIs and interoperability standards.

*SCADA: Supervisory Control and Data Acquisition; AMI: Advanced Metering Infrastructure; GIS: Geospatial Information Systems

Transferable lesson

Digital infrastructure creates value when it improves decisions and delivery – making constraints visible earlier, connections faster, flexibility usable, outages easier to manage and investment better targeted.

Case: Demand flexibility depends on products, markets and trust

Demand flexibility starts at the product level. Flexible demand cannot scale if appliances, chargers and devices cannot respond to grid signals, markets cannot use that response, or consumers do not trust the proposition.

Product readiness

- Priority appliances should be demand-response-ready: ACs, water heaters, heat pumps, refrigeration and EV chargers.
- Standards and certification should support flexibility without compromising efficiency or service quality.

Interoperability

- Open communication standards and common protocols avoid fragmented markets.
- Testing and certification help ensure products deliver the flexibility expected by consumers and system operators.

Consumer participation

- Consent, data protection, opt-outs, fair compensation and simple propositions are essential.
- Flexibility programs need to be beneficial and low-friction for households and firms.

Australia example

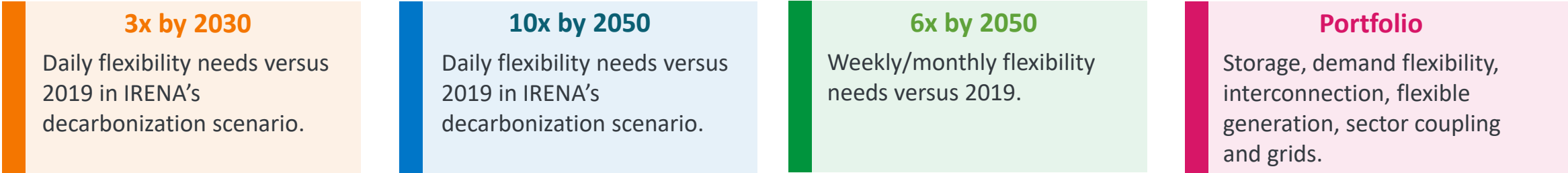
Demand-response capability standards and peak-demand reduction programs show how product policy can prepare appliances for flexibility markets before high penetration creates operational stress.

Transferable lesson

Demand flexibility starts with design, not dispatch. Products, standards, interoperability and consumer rules determine whether flexible demand can become a dependable system resource

Flexibility must become a core power system resource

That means *planning* for it, *valuing* it, *procuring* it and *integrating* it into system operations — so electrified demand can be served reliably and affordably.



Dimension	What this means for strategic electrification
Planning	Conduct country-level flexibility assessments; quantify needs by timeframe, geography, operating condition and reliability contribution.
Investment	Balance grid and flexibility investment, recognizing their complementary roles for reliable and cost-effective supply.
Markets	Enable appropriate incentives, revenue models and procurement mechanisms for flexibility resources.
Operations	Integrate flexibility into dispatch, reserves, congestion management and renewable integration.
Coordination	Align planning, investment, market rules and operations rather than treating flexibility as a series of pilots.

Strategic insight

The strategic task is to institutionalize flexibility: quantify needs by time and location, compare flexibility with grid reinforcement, create procurement and market routes, and embed reliable resources in system operations.

Turning plans into investment signals

Targets do not finance projects. Capital moves when plans show sequencing, ownership, risk treatment and credible pipelines.

What investors and finance ministries want to see

1. **Direction and sequencing:** Clear assumptions, system direction, cost visibility and timing.
2. **Implementation pathway:** Milestones, procurement routes, permits, grid-readiness dependencies and policy packages.
3. **Institutional anchoring:** Named owners able to update, defend and implement the plan as assumptions change.
4. **Risk treatment:** Fiscal strategy, guarantees, MDB/DFI instruments, regulatory risk allocation and de-risking tools.
5. **Project pipeline:** Mature, conditional and concept-level opportunities — including credible demand commitments and connection assumptions where relevant — distinguished so capital can assess more than the first project.

Implementation test

Can investors and finance ministries read the plan and see credible projects, delivery milestones, risk treatment and decision points — or is it still a target document without an investment pathway?

CEM can help move grid modernization from analysis to delivery

Practical cooperation can help countries apply proven approaches to grid utilization, flexibility, digital readiness and investment sequencing.

Track	Focus	Lead fit / participants
Grid-utilization clinics	Compare hosting-capacity maps, calculated capacity, non-firm access, queue management and GETs/ATTs deployment.	ISGAN WG3, with regulators and system operators.
Operational flexibility track	Link DERs, VPPs, storage, flexible appliances and demand response to planning, connection agreements, markets and operations.	Joint ISGAN-GPFM work on flexibility and grid upgrades, SEAD.
Digital readiness pathway	Support data governance, secure data spaces, interoperability, AI sandboxes, model monitoring and cybersecurity-by-design.	WG6/GPFM, SEAD, and digital and system-operation experts.
Planning-to-investment exchange	Connect planning outputs to procurement, finance ministries, MDBs/DFIs, utilities and project pipelines.	LTES/GCEP, with finance actors.
Country Action Plans	Test how permitting, grid utilization, flexibility, digitalization and finance reforms combine in real country contexts.	2–3 volunteer countries, supported by relevant CEM workstreams and finance/delivery partners.

CEM opportunity

Launch a Grid Utilization and Flexibility Action Track that helps countries diagnose where capacity is hidden, where flexibility can avoid or defer reinforcement, and which regulatory or market reforms are needed to make those options usable.

04

Manage fuel, physical and cyber risks in electrified systems

Electrification can reduce fossil-fuel exposure, but it also creates new dependencies on reliable electricity, resilient infrastructure, secure digital systems and robust supply chains.



Strategic electrification shifts the energy-security risk map

Fuel exposure can fall - but reliability, resilience, cybersecurity and supply-chain strength become more important as economies depend more heavily on electricity.

Fuel and Import exposure

- Electrification can reduce fossil-fuel import dependence and exposure to price volatility.
- Security benefits depend on domestic clean-power buildout, grids, storage, flexibility and efficient demand.
- Power-to-X can reduce fuel exposure in hard-to-electrify sectors if supply is clean and reliable.

Physical Resilience

- Heat, drought, wildfire, storms and flooding affect generation, transmission, distribution, equipment ratings and restoration.
- Electrification increases the consequences of outages where transport, heating, cooling and critical services depend on electricity.

Cybersecurity

- Digitalised, decentralised and AI-enabled systems increase cyber attack surfaces.
- DER platforms, market systems, data exchanges and operational tools require cyber-by-design governance.
- Recovery and fallback procedures matter as much as prevention.

Supply chain and Industrial risks

- Transformers, cables, switchgear, power electronics, critical minerals, skilled labour and digital equipment can become delivery bottlenecks.
- These risks should be tested against deployment schedules, not treated as generic procurement issues.

Sector-coupling risks

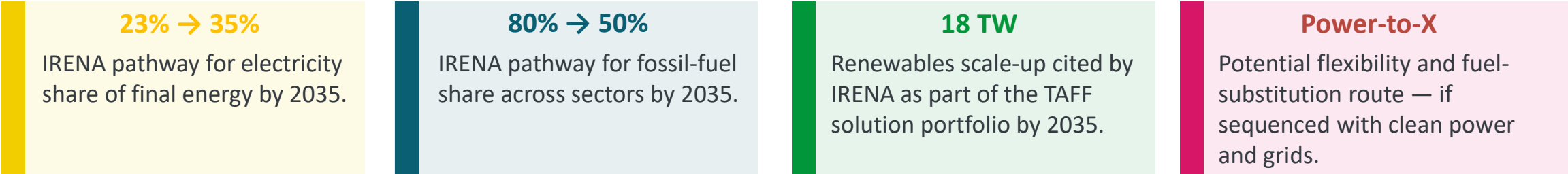
- Hydrogen, Power-to-X, EV charging, heat and data centers can provide flexibility – but also create new dependencies across electricity, fuels, water, land, telecoms, industry and transport.

Strategic insight

The energy-security test is no longer only whether countries can secure fuels; it is whether they can deliver clean electricity reliably, affordably, flexibly and securely under stress.

Electrification can reduce fuel risk - but only if delivery capacity keeps up

Electrification reduces fossil-fuel exposure when clean power, grids, storage, flexibility and efficient demand scale fast enough to replace fuel dependence with reliable electricity service.



Issue	Synthesis
Security benefit	Reduce fossil import exposure, price volatility and vulnerability to fuel-supply shocks.
Implementation condition	Domestic renewables, grids, interconnection, storage, flexibility and efficient demand must scale fast enough.
Risk to manage	A poorly sequenced shift can replace fuel vulnerability with electricity reliability, grid, component or cyber vulnerability.
CEM comparison	Countries can compare how they define energy security in electrified systems: fuel exposure, resilience, affordability, cyber, critical loads and supply chains.

Strategic insight
Electrification cuts fuel exposure only when clean power, grids, storage, flexibility and efficient demand scale fast enough to provide reliable electricity service. Otherwise, countries exchange one security risk for another.

Cybersecurity must be built into digitalized electrification

As power systems become more digital, decentralized and data-rich, cybersecurity becomes part of strategic electrification — not a separate technical issue to resolve later.

New attack surfaces

- DER platforms, VPPs, smart charging, AI tools, data exchanges and market platforms expand the perimeter.
- Remote access and cloud-connected devices can create operational vulnerabilities.
- Data availability and interoperability must be balanced with security and privacy.

Governance requirements

- Clear roles for data ownership, access and accountability.
- Security standards, auditability, incident reporting and recovery procedures.
- Human oversight and fallback modes for AI-assisted operational tools.

Implementation pathway

- Start with advisory tools and sandboxes.
- Move into operational use only when responsibilities are clear, safeguards are tested, decisions can be audited, and cyber risks are managed.
- Test cyber resilience before scaling automation.

CEM opportunity

Create a trusted, non-sensitive exchange on cybersecurity governance for digitalized grids, DER platforms, VPPs, smart charging, AI tools and critical electricity services, focused on roles, standards, auditability, incident response, recovery and fallback procedures.

Physical resilience must be built into electrification plans - not added later

As more social and economic functions depend on electricity, climate and weather risks become core electrification risks rather than separate resilience issues.

Risk channels

- Heat raises cooling demand and can reduce equipment ratings.
- Drought affects hydropower and cooling water availability.
- Wildfire, storms and flooding damage lines, substations and access routes.

Planning implications

- Use climate/weather stress tests for demand, generation and network performance.
- Update asset standards and restoration assumptions as risks shift.
- Prioritize critical services: hospitals, water, telecoms, transport and cooling centers.

Tools

- Hardening, undergrounding where justified, vegetation management and redundancy.
- Distributed resilience: batteries, microgrids, demand flexibility and priority restoration.
- Data/AI for inspection, outage prediction and restoration.

Implementation test

Does the electrification plan identify critical loads, resilience standards, restoration priorities and funding routes?

Delivery bottlenecks are now energy-security risks

Electrification strategies can fail even when policies are strong if grids, transformers, cables, power electronics, software systems and skilled labor are not available on time.

Grid and component bottlenecks

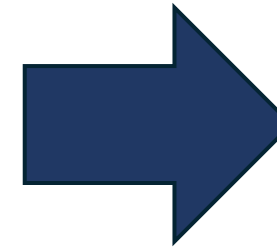
- Transformers, switchgear, cables, advanced conductors and power electronics can face long lead times.
- Rising demand for grid equipment can increase costs and delay infrastructure buildout.
- Component availability should be tested against deployment schedules.

Clean-tech and mineral dependencies

- Critical minerals and manufacturing concentration can affect batteries, solar, wind, power electronics and digital hardware.
- Manufacturing capacity for both supply-side and industrial end-use technologies
- Risks differ by region and technology pathway.
- Diversification, recycling and standards can reduce vulnerability.

Links to workforce and finance

- Skilled labor is also a supply chain: line workers, electricians, engineers, operators, regulators and permitting staff can become the limiting input.
- Higher component costs and uncertain lead times raise financing risk, so plans need realistic procurement windows, milestones and risk treatment.



Institutional response

- Map bottlenecks by technology and timeline.
- Use procurement and planning to signal demand early.
- Coordinate energy, industry, trade, finance and skills policy.

Transferable lesson

Supply-chain resilience is a delivery test, not a procurement afterthought. Countries will benefit from testing transformers, cables, power electronics, minerals, software and skilled labor against actual deployment timelines.

Risk ownership is fragmented across institutions

Fuel security, cyber, physical resilience, supply chains and power-system reliability are often handled by different institutions. Strategic electrification needs a shared risk view across them.

Five Risk Integration Tests

1. Shared risk register

- Do electrification plans bring fuel exposure, cyber, physical resilience, supply chains and reliability into one shared risk register?

2. Trusted information-sharing

- Are there safe, non-sensitive ways to exchange cybersecurity and resilience lessons without exposing operational vulnerabilities?

3. Delivery-tested security

- Are security claims tested against grid buildout, storage, flexibility, permitting, operations and component availability – or only against generation targets?

4. Updated standards and stress tests

- Do planning assumptions, asset ratings, weather norms and restoration strategies reflect changing climate, load and electrification patterns?

5. Interdependency mapping

- Do plans map how hydrogen, EV charging, data centers, cooling and digital infrastructure link electricity with water, telecoms, land, industry and transport?

Implementation test

Are resilience and security built into electrification decisions while pathways are being designed — or added after generation, grid and investment choices have already been locked in?

CEM can help countries integrate risk into strategic electrification plans

CEM can help countries stress-test electrification pathways against practical risks: fuel shocks, cyber incidents, extreme weather, component shortages and critical-load failures.

Action track	Focus	CEM cooperation opportunity
Integrated risk planning	Require strategic electrification plans to test fuel shocks, cyber incidents, extreme weather, component shortages and critical-load failure scenarios.	Develop a light-touch risk-taxonomy template for country Action Plans.
Cyber-by-design pathways	Use common principles for governance, auditability, human oversight, data access, secure operations and recovery procedures.	Create a trusted, non-sensitive cyber governance exchange for digitalized grids, DERs and AI tools.
Physical resilience stress tests	Compare climate and weather stress tests, grid resilience standards, asset hardening, restoration planning and critical-service prioritization.	Run practitioner clinics with system operators, regulators and resilience agencies.
Supply-chain visibility	Track bottlenecks in transformers, cables, switchgear, power electronics, minerals and skilled labor; align procurement with deployment timelines.	Peer exchange on bottleneck mapping, procurement timing and supply-chain resilience.
Interdependency mapping	Assess how Power-to-X, hydrogen, heat, EVs, data centers and telecoms affect electricity-system risk and flexibility.	Country case clinics on sector-coupled resilience and critical loads.

CEM opportunity

Convene Fuel, Physical and Cyber Risk Workshops linked to country Action Plans, with light-touch templates for risk registers, stress tests, critical-load mapping and cyber-by-design principles.

05

Build the workforce and institutions to deliver

Strategic electrification depends on the people and institutions able to plan, build, operate, regulate and maintain the system — from electricians and engineers to system operators, permitting authorities and regulators.



Workforce and institutions can become a binding constraint

Strategic electrification will not be delivered by targets, capital and technology alone. Countries need enough people, in the right occupations and institutions, at the right time and in the right places.

76 million

Global energy employment in 2024.

~60%

Share of surveyed energy companies reporting labor shortages that put timelines, reliability and cost control at risk.

+15 million

Additional global energy workers needed by 2035 in a net-zero-aligned pathway.

40%

Approximate increase in energy-relevant graduates needed globally by 2030 to prevent skills mismatch worsening.

Technical workforce

- Electricians, power-line workers, technicians, engineers, installers, operators and digital specialists.
- Applied technical roles are among the most exposed to shortages.
- Manufacturing, installation and maintenance skills all matter.

Institutional Capacity

- Regulators, planners, system operators, permitting authorities and local governments need capacity.
- Higher education, TVET institutions, including instructors need capacity to develop and update curricula to be inclusive and responsive to evolving skills needs.
- Public-sector bottlenecks can delay delivery as much as private-sector labor shortages.
- Digital and cyber skills become core power-system competencies.

Just transition lens

- Workforce strategies should support good jobs, inclusion of marginalized groups (including women and youth), and economic opportunities across regions.
- Workers and regions affected by fossil-fuel decline need credible pathways
- Social dialogue can improve legitimacy and delivery.

Strategic insight

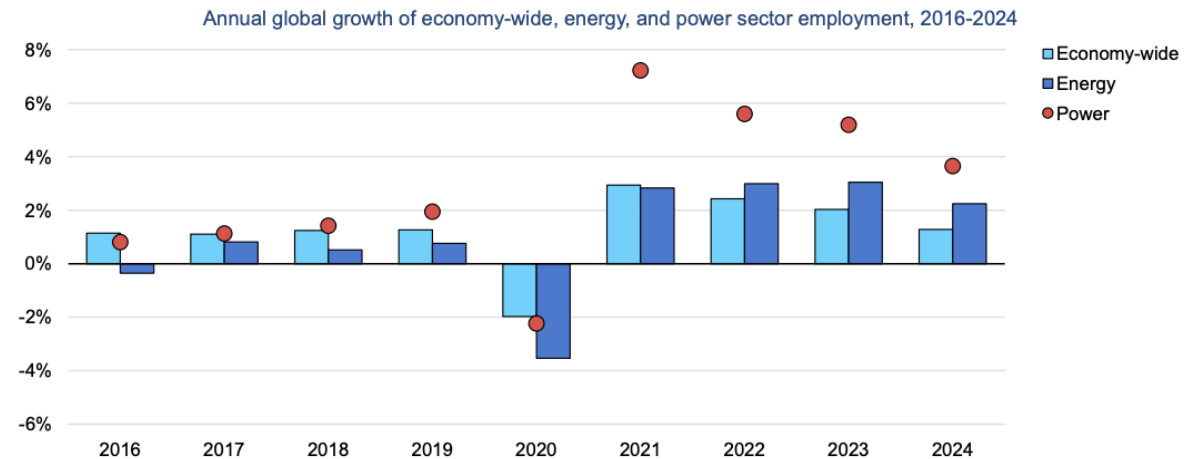
Workforce is delivery infrastructure. Without the right occupations, institutions and training pathways in the right places, capital and technology will not translate into projects.

Power-sector jobs are growing fast — but growth alone does not solve the skills problem

The employment shift is already underway; the next challenge is ensuring that growth translates into the specific skills needed for grids, storage, renewables, digital systems and system operation.

- **Employment Expansion:** Global energy employment reached 76m workers in 2024 (growing twice as fast as the wider economy), with the power sector driving growth since 2020.
- **Delivery Constraint:** Strategic electrification depends entirely on having a skilled workforce to design, manufacture, install, operate, and maintain equipment.
- **Workforce and Capacity Constraints:** In grid roles, 1.4 workers are nearing retirement for every young entrant, while women make up <5% of the workers in trades occupations (electricians, and line workers).
- **Global Cooperation:** Countries can close workforce gaps faster by sharing skills data, training models, qualification standards, curricula and mutual-recognition approaches.

The power sector has underpinned strong energy employment growth since 2020, as the energy sector entered the Age of Electricity



IEA. CC BY 4.0.

Note: Power includes employment in power generation and transmission, distribution and storage.

Source: IEA, *World Energy Employment 2025*, International Energy Agency, Paris, 2025.

Strategic insight

Power-sector job growth is not the same as workforce readiness. The bottleneck is whether countries can build the specific occupations, training systems and public institutions needed before deployment timelines tighten.

The workforce problem is specificity, timing and institutional capacity

The issue is not just “more jobs”. The delivery problem is matching specific occupations, training systems and institutions to the deployment pathway.

Barrier	Why it matters	Strategic shift
Separate planning processes	Energy-transition plans and workforce plans often proceed separately, even though technology pathways determine occupational needs.	Integrate workforce requirements into energy and climate plans early.
Wrong level of detail	Total jobs estimates hide whether future demand concerns electricians, technicians, engineers, digital specialists or regulators.	Move from jobs totals to occupation- and skill-level forecasting.
Territorial mismatch	Worker availability, firms, training providers and deployment needs vary by region, so national numbers can mask local shortages.	Use regional skills assessments and place-based workforce planning.
Training costs and lead times	Childcare, transport, and upfront costs deter women, young people, and rural communities from gaining access; Skills cannot be created instantly- waiting until deployment starts turns workforce into a constraint.	Conduct targeted outreach, provide inclusive financial instruments, childcare, and mentoring; act early through TVET, apprenticeships, reskilling, upskilling and career pathways.
Institutional bottlenecks	Regulators, planners, utilities, system operators and permitting authorities need staff, data and expertise. Regulatory roles are expanding as electrification, DERs, flexibility, digitalization and new technologies reshape the system.	Treat institutions as delivery infrastructure. Use regulatory and institutional capability assessments to identify gaps in mandates, workloads, skills and processes.

Strategic insight

Skills and institutional capacity need to be planned before deployment starts – by occupation, region, timing and delivery function.

Case: Workforce planning needs a territorial and just-transition lens

France, Denmark and Italy show that workforce planning becomes more actionable when national skills concerns are translated into regional assessments, employer partnerships and visible technical career pathways.

France: Regional skills assessment

Regional agreements in four pilot regions analysed how the green transition affects occupations and training needs.

Lesson: national energy plans need a territorial skills lens and regional implementation partnerships.

Denmark: Local green skills gaps

Copenhagen combined green career guidance, vocational education, employer reskilling, upskilling courses and internships.

Lesson: city and regional action can connect employers, training providers and learners.

Italy: technical workforce pipeline

Recruitment difficulties for technical and graduate profiles require action upstream.

Lesson: career orientation and education-industry links can make energy careers more visible and attractive.

Just Transition

Workforce planning should expand access to good energy jobs while supporting workers and regions affected by fossil-fuel decline. That means linking skills strategies to inclusion for marginalized groups, regional opportunity, social dialogue and credible pathways into new roles.

Transferable lesson

Workforce planning needs a territorial and just-transition lens. Countries will benefit from translating technology pathways into occupation-level needs early, then building regional partnerships that connect employers, training providers, public institutions, workers and communities.

Case: Championing Inclusion- Empowering Women, and Youth for the Energy Transition

Equality in Energy Transitions Initiative

This Initiative is an IEA and CEM network dedicated to advancing gender equality across the global clean energy sector. Its flagship "Equal by 30" campaign has mobilized 237 signatories to publish over 390 collective commitments spanning equal pay, leadership, workplace safety, and inclusive culture across diverse industries, including renewables, energy efficiency, and nuclear power.

Lesson: Establishing structured, multi-dimensional voluntary frameworks enables diverse energy organizations to move beyond general diversity goals into concrete, accountable commitments—proving that international networks can successfully institutionalize equity as an operational best practice for the clean energy transition.

Patriot Energy, Indonesia

An Indonesian government initiative that deploys promising young professionals and youth to remote, underserved communities to spearhead local renewable energy development, expand electricity access, and empower local populations.

Lesson: Direct grassroots deployment initiatives effectively engage youth in the clean energy transition by providing young professionals with real-world technical and community-building field experience, simultaneously bridging energy poverty gaps in remote regions.

Transferable lesson

A truly just and sustainable clean energy transition requires intentional human-capital frameworks that actively engage and empower underrepresented groups across every level—bridging the gap between high-level structural accountability (such as corporate equity and diversity pledges) and grassroots, on-the-ground field execution (such as deploying youth talent to underserved communities).

A practical cycle for workforce and institutional readiness

A practical workforce strategy starts with technology pathways, then works backwards to the occupations, regions, training systems, partnerships and institutions needed to deliver them.

Step		What countries need to do
1	Translate technology and industrial value-chain pathways	Convert deployment scenarios into future occupational needs for grids, renewables, storage, EVs, cooling, efficiency, digital systems and public-sector functions.
2	Map territorial supply	Assess current workers, training providers, firms, public institutions and regional labor-market conditions with data disaggregated by gender, age, and region.
3	Identify gaps and timing	Compare demand and supply by occupation, region and year; distinguish immediate shortages from future pipeline risks.
4	Act through partnerships	Use TVET, apprenticeships, employer partnerships, union/social dialogue, inclusive recruitment, certification, reskilling and institutional capacity-building.
5	Monitor and adjust	Track shortages, completions, worker mobility, diversity, job placement and retention rates, project delays and regulatory capacity as part of energy-plan implementation.

Strategic insight

Workforce and institutional capacity should be treated like infrastructure: planned before deployment, financed explicitly, sequenced by region and occupation, and monitored as a delivery risk.

CEM can help countries turn workforce needs into delivery capacity

CEM can help countries turn workforce concern into delivery capacity by comparing skills forecasting, regional partnerships, institutional capacity-building, qualification standards and just-transition approaches.

Action track	Focus	CEM cooperation opportunity
Integrate workforce into plans	Build workforce requirements into energy and climate plans, NDC updates and sector strategies; translate deployment pathways into future occupation, skill and training needs, including public-sector and regulatory capacity.	Develop a template for workforce requirements in country Action Plans.
Move from jobs to skills	Identify professional profiles by technology, value-chain stage, geography and timeframe; improve labor-market data and forecast skill supply and demand by occupation and region.	Share methods for occupation-level forecasting, regional skills assessment and labor-market data.
Act on current and emerging gaps	Target TVET, apprenticeships, upskilling, reskilling, attraction and retention before bottlenecks emerge; include digital skills, manufacturing, decentralized energy and enabling skills in policy, finance, law, education and business.	Compare public-private training models, curricula, certification approaches and employer partnerships.
Build institutions	Invest in regulators, system operators, permitting authorities, utilities and local governments as delivery infrastructure. Use Regulatory Health Checks to assess mandates, governance, workloads, skills and processes, including capacity in system planning, flexibility, data, finance and emerging technologies.	Peer exchange on regulatory capability, training, secondments and technical assistance.
Strengthen partnerships and standards	Foster collaboration between governments, industry, labor, civil society and training providers; strengthen qualification standards, mutual recognition and clean-energy competencies in curricula.	Share approaches to qualification standards, mutual recognition, curricula and international cooperation on skills; engage with the 'Empowering Societies Action Agenda.
Keep just transition explicit	Support inclusion of marginalized groups, regional opportunity, social dialogue and pathways for workers affected by fossil-fuel decline.	Share best practices and lessons learned related to inclusive workforce strategies and labor transition.

CEM opportunity

Launch a Workforce and Institutional Capacity Peer-to-Peer effort focused on skills forecasting, regional delivery partnerships, qualification standards, regulatory capacity and inclusive workforce strategies.

Strategic Electrification: From report to implementation

CEM17 can turn strategic electrification from a shared priority into a practical cooperation agenda, with countries and initiatives carrying the work from Riyadh into COP31 and 2027.

Strategic electrification: A practical action agenda

Together, the five themes give CEM a practical cooperation agenda: helping countries plan demand, keep electrification affordable, modernize grids, manage new risks, and build the people and institutions needed to deliver. The most practical starting point is where the themes intersect: demand growth planning, grid utilization, flexibility, affordability and investment sequencing.

Agreed key topic	Core implementation message
1. Plan and shape rising electricity demand	Forecast by end-use, location, time, weather, credibility and flexibility; integrate efficiency and large-load transparency before demand locks into generation and network needs.
2. Keep electrification affordable through least-cost system design	Use efficient products, tariffs, flexible demand, probabilistic planning and non-wire alternatives to reduce unnecessary peak-driven investment and protect consumers.
3. Modernize infrastructure, increase system utilization and unlock flexibility	Combine permitting reform, hosting maps, GETs/ATTs, flexible connections, DERs/VPPs, digitalization, AI and credible investment pipelines.
4. Manage fuel, physical and cyber risks in electrified	Embed fuel, physical, cyber, supply-chain and operational resilience into strategic electrification planning.
5. Build the workforce and institutions to deliver	Treat workforce, skills, regulatory capacity, institutions and just transition as core delivery enablers, not co-benefits.

CEM opportunity

CEM's comparative advantage is practical cooperation: Helping countries learn from shared delivery problems and turning that learning into Action Plans, clinics, templates and tools they can use in 2027.

A Potential CEM17 collaboration package

A focused CEM17 package can give countries practical routes into follow-up work: Action Plans, practitioner clinics, common templates and public-private exchange.

Element	Purpose	Possible output
Report launch	Present the report as an implementation guide, not only a publication.	Invite countries and initiatives into follow-up tracks.
Country Action Plans	Use a small cohort to show how strategic electrification becomes institutional choices, investment sequencing and milestones.	2–3 countries by COP31; more in 2027.
Practitioner clinics – purpose	Targeted sessions on demand planning, grid utilization/flexibility, affordability, risk frameworks and workforce planning, with a priority clinic on turning flexible demand and grid utilization into near-term delivery options.	2–3 clinics before COP31; workplan for 2027.
Common templates – purpose	Develop light-touch templates for demand profiles, flexible-load valuation, local flexibility procurement, non-firm connections, risk checks and workforce assessments.	Outputs countries can actually use in 2027.
Public-private exchange	Bring government, system operators, utilities, technology providers, investors and civil society around concrete implementation barriers.	Use business input where it improves planning and delivery, not as generic consultation.

Implementation test

By COP31, can each track point to one usable 2027 output – a template, diagnostic, Action Plan, case library or clinic result?

From CEM17 to COP31 and 2027: From report to delivery

A shared delivery timeline can help 21CPP, countries and partner initiatives coordinate next steps, show early progress by COP31, and build a credible 2027 implementation workplan.

Moment	What should happen
CEM17 Riyadh	Launch report; invite countries into a small number of action-oriented follow-up tracks, Action Plans and practitioner clinics.
Oct–Nov 2026	Run initial clinics; gather country examples; identify 2027 workplan owners, partner contributions, resourcing needs and expected outputs.
COP31 Antalya	Show early delivery: country Action Plans, priority findings, partner commitments and a practical 2027 cooperation agenda.
2027 implementation	Move from thought leadership to workstreams on demand planning, affordability/flexibility, infrastructure, risk and workforce capacity.

Implementation test

By COP31, has 21CPP moved from report launch to named countries, named workstream owners, agreed partner contributions and at least one usable output for 2027?

Recommended priority collaboration tracks

Prioritizing a small number of targeted collaboration tracks can help CEM concentrate effort where countries face common implementation challenges and where peer learning can produce usable tools quickly.

Track	Focus	2027 output
A. Demand growth planning	EVs, cooling, data centers, industry, hydrogen, other large loads, bottom-up profiles and credible-demand signals.	Demand-planning clinic series, large-load transparency template and credible-demand test.
B. Grid utilization and flexibility	GETs/ATTs, hosting-capacity maps, non-firm access, DER/VPP integration, flexibility procurement and regulatory readiness.	Grid-utilization action track with case library, connection-reform checklist, flexibility procurement template and regulatory-readiness diagnostic.
C. Affordability and consumers	Efficient products, tariffs, flexibility valuation, consumer safeguards and market access.	Peer-learning stream on tariff/flexibility design and affordability protections.
D. Fuel, physical and cyber risks	Fuel exposure, cyber governance, physical resilience, supply chains and operational standards.	Non-sensitive risk-framework exchange and country stress-test principles.
E. Workforce and institutions	Skills forecasts, TVET, regulator capacity, institutional readiness, local delivery institutions and just transition.	Workforce and institutional-capacity assessment template, with optional regulatory-readiness module.

CEM opportunity

The strongest initial work package would combine Tracks A and B: demand growth planning with grid utilization and flexibility. The practical output could be a country-facing diagnostic and toolkit that helps countries identify where demand will appear, where the grid is constrained, which loads can flex, and which non-wire or regulatory options can reduce cost and speed connection. Tracks C–E should remain visible as enabling workstreams and be developed where there is member demand and delivery capacity.

Strategic electrification is the implementation test of the clean energy transition

CEM can help countries turn strategic electrification into practical delivery: connecting demand, grids, markets, finance, resilience, workforce and institutions so the clean energy transition becomes faster, more secure and more affordable.

What Countries Need

- Not just more electricity – a system able to use it well.
- Actionable demand plans.
- Reliable, affordable, secure and flexible power systems.
- Institutions able to implement.

What CEM can do

- Help countries learn faster from shared implementation problems.
- Create clinics, peer exchanges, templates and Action Plans.
- Connect public, private and technical actors.

What 21CPP can offer

- A practical bridge from thought leadership to delivery
- A neutral space for member initiatives to combine expertise.
- A route from CEM17 launch to COP31 follow-up and 2027 workstreams.
- A route to country-facing diagnostics, templates and technical support that help turn peer learning into implementation.

Strategic insight

Strategic electrification succeeds when demand, grids, markets, finance, resilience, workforce and institutions move together. 21CPP can help make that coordination practical: turning shared insight into country action, usable tools and implementation support.



Annexes

Acronyms

Acronym	Full-form
DSO	Distribution System Operator
DER/VPP	Distributed Energy Resources/ Virtual Power Plant
GETs/ATTs	Grid Enhancing Technologies/Advanced Transmission Technologies
GW	Gigawatt
IRP	Integrated Resource Plan
LV	Low Voltage
MEPS	Minimum Energy Performance Standards
MDB/DFI	Multilateral Development Bank/Development Finance Institutions
PAC	Paris Agreement Compatible
PV	Photovoltaic
TAFF	Transition Away from Fossil Fuels
TVET	Technical and Vocational Education and Training
TSO	Transmission System Operator
TWh	Terrawatt-Hour

Contributing Workstreams and Initiatives

CEM Workstream	Brief Description
21CPP - 21st Century Power Partnership	Aims to accelerate the global transformation of power systems. It serves as a platform for public-private collaboration to advance integrated policy, regulatory, financial, and technical solutions for the large-scale deployment of renewable energy in combination with deep energy efficiency and smart grid solutions.
ISGAN - International Smart Grid Action Network	International government-level platform that facilitates the development and exchange of knowledge and expertise on smarter, cleaner and more flexible electricity grids, accelerating the development, deployment and effective integration of smart grid technologies worldwide.
IRENA - International Renewable Energy Agency	Global intergovernmental organization dedicated exclusively to promoting renewable energy adoption and supporting countries in their transition to a sustainable energy future. Coordinating the LTES initiative.
EVI - Electric Vehicles Initiative	Aimed at accelerating the introduction and adoption of electric vehicles worldwide. The initiative seeks to significantly reduce carbon and air pollutant emissions from vehicles and catalyze the clean transportation economy by accelerating the introduction and adoption of zero-emission vehicles in all vehicle classes.
ERAD - Empowering Regulators for Accelerated Decarbonisation	Global initiative aimed at enhancing the role of regulators in the clean energy transition. It focuses on aligning regulatory actions with national decarbonization goals and accelerating solutions for the clean energy transition.
LTES - Long-Term Scenarios for the Energy Transition	Initiative aimed to promote the improved use of model-based long-term energy scenarios to support and accelerate the energy transition in CEM countries. It coordinated by IRENA, bringing together a community of 28 member governments and 12 technical partners. The LTES Initiative focuses on strengthening scenario development, improving scenario use, and putting fairness and social justice at the heart of the clean energy transition.
SEAD - Super-efficient Equipment and Appliance Deployment	Voluntary collaboration among governments to promote the manufacture, purchase, and use of energy-efficient appliances, lighting, and equipment worldwide. SEAD is coordinated by the International Energy Agency. SEAD's 23 participating governments work together to move global markets towards affordable products that provide better services with less energy.
GPFM -Green Powered Future Mission	MI Mission with the goal to demonstrate that power systems in different geographies and climates can effectively integrate up to 100% variable renewable energy (VRE) in their generation mix by 2030 while maintaining a cost-efficient, secure, and resilient system.
IDDI - Industrial Deep Decarbonization Initiative	Global coalition of public and private organizations, coordinated by the United Nation Industrial Development Organization (UNIDO), working to stimulate demand for low carbon industrial materials. The initiative aims to decarbonize heavy industries, starting with steel, cement, and concrete.

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