



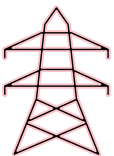
**INTERCONNECTION
INNOVATION e-XCHANGE**
U.S. DEPARTMENT OF ENERGY

Transmission Interconnection Roadmap

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*An initiative by the Solar Energy Technologies Office and the Wind Energy Technologies Office
With support from Lawrence Berkeley National Lab and Pacific Northwest National Lab*



WETO Systems Integration

Key Activities

Transmission Adequacy and Access

Transmission planning analysis, interconnection improvement, and transmission technology innovation

Grid Reliability and Resilience

Wind control for grid services, grid monitoring and control, grid stability analysis with increasing IBRs

Wind Hybrid System

Analysis, design, configuration, control, and modeling

Wind Cybersecurity

Hardening legacy systems, tools and information sharing, cybersecurity by design, supply chain

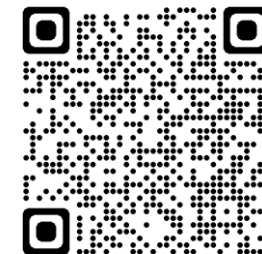
Offshore Initiatives

- Atlantic and West Coast Offshore Wind Transmission Studies
- FOA 2828 HVDC Standards, Functional Requirements, and Education for Offshore Wind
- FOA 3141 Innovative Designs for high performance, low cost HVDC Converters
- Wind Production Database
- Understanding Atlantic Offshore Grid Protection

Other Major Initiatives

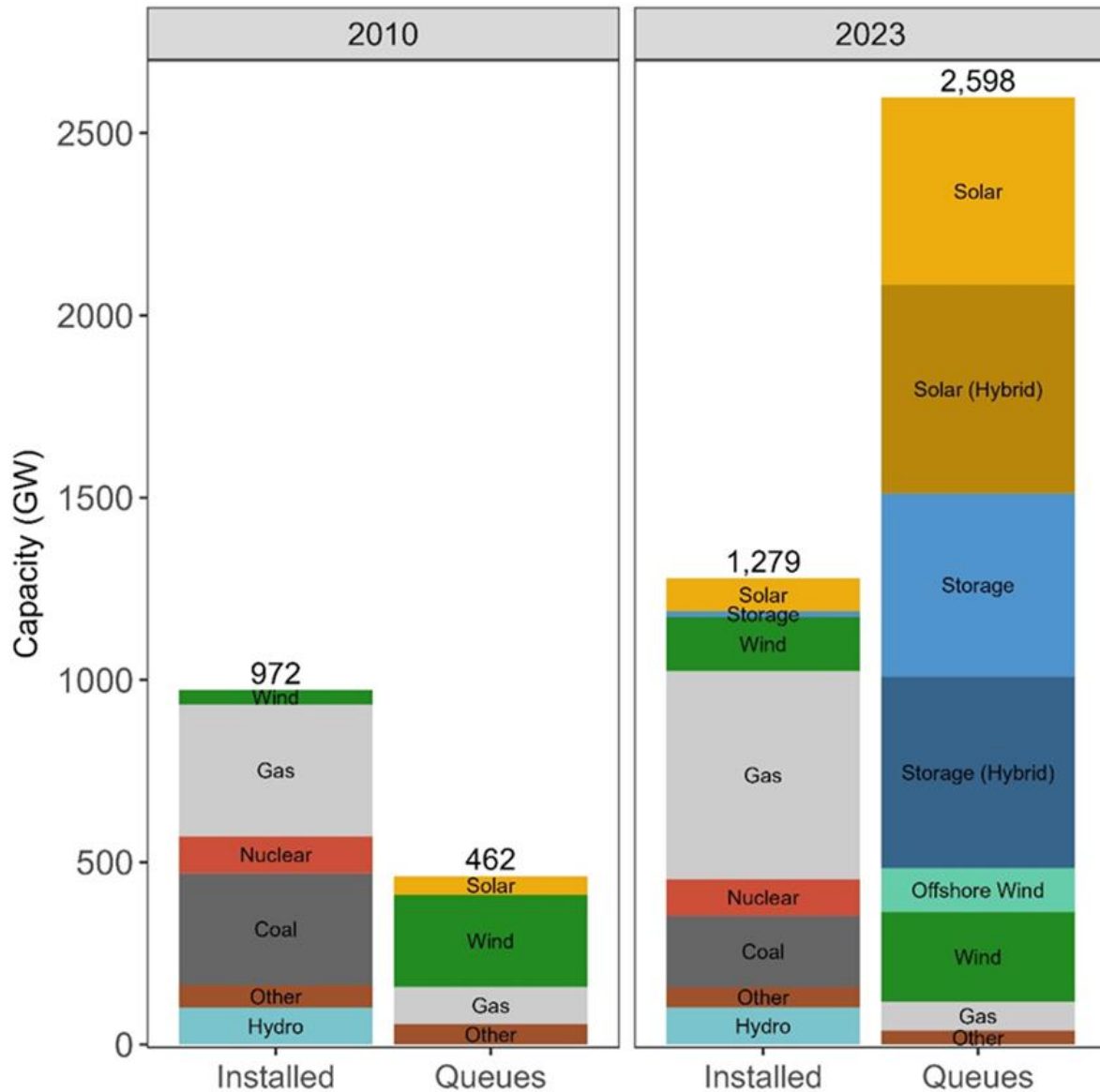
- Interconnection Innovation Exchange
- UNIFI consortium (grid forming inverters)
- FOA 2745 Solar and Wind Grid Service and Reliability Demonstration
- Wind Cybersecurity Lab Call
- Wind-H2-Green Steel/Green Ammonia

Vineyard I



Atlantic Offshore Wind Transmission Study

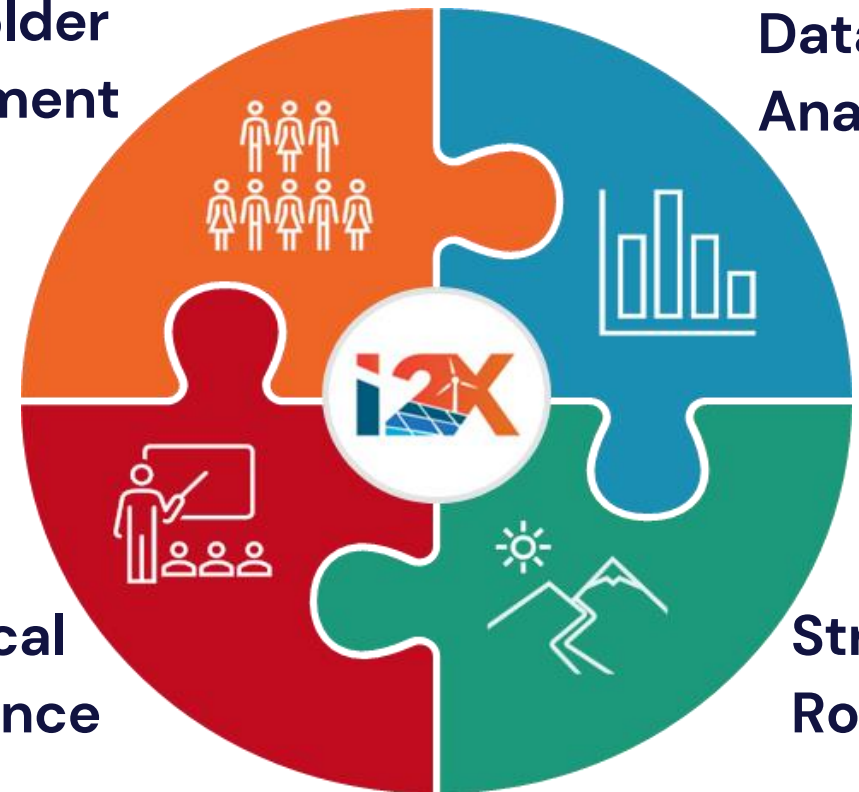
Transmission Interconnection Status and i2X



Mission: To enable a **simpler, faster, and fairer** interconnection of clean energy resources all while enhancing the **reliability, resiliency, and security** of our electric grid.

Stakeholder Engagement

Data & Analytics



Technical Assistance

Strategic Roadmap

Context and Frame of Interconnection Roadmap

Roadmap Engagement

Solution e-Xchanges

- Informed by 2,075+ stakeholders at 350 organizations during 22 Solution e-Xchange meetings and 20+ public events

Draft Roadmap

- 35 solutions under 4 goals
- Solicited comments from EERE, SA, VTO, IEDO and DOE's GDO, OP, OP Workforce EJE, OE, NE, FECM, and CESER

RFI Responses

- 40 organizations (e.g., EEI, AES, ACP, SEIA, NRECA)
- Five ISOs/RTOs
- Total of ~280 comments
- Comments incorporated into the Final draft that was sent to DOE staff again for comments

Key Roadmap Components

Solutions and implementation time frames:

- Short-term: within 1-3 years (before 2027)
- Medium-term: 3-5 years (by 2029)
- Long-term: beyond 5 years (2030+)

Solution actors:

- Transmission providers (Utilities, ISOs, BAs)
- Regulators (FERC/NERC, State PUCs)
- Interconnection customers
- Consumer Groups
- Research community (including DOE)
- OEM and software vendors
- State, local, tribal governments
- Equity and public benefit organizations

DOE plays multiple roles: convening stakeholders, facilitating solution adoption, providing technical assistance, supporting the research community, and can also become a solution provider.

Measuring interconnection success

Interconnection processes align well with Federal, state, and customer's decarbonization goals



Reduced interconnection process time
Average time from request to agreement

Target Value by 2030

< 12 months

Recent Value

33 months (2022)



Lowered cost uncertainty
Standard deviation of interconnection costs

< \$150/kW

\$551/kW (2020-2021)



Increased late-stage completion rates
Completion rate for projects that entered facility study phase

> 70%

45% (2016)



Maintained system reliability
Number of system disturbances due to modeling inaccuracy

Zero

4 (2022)

35 Solutions Organized by Four Interconnection Goals

Goal #1: Increase Data Access and Transparency

- Highlight improvements that **go beyond** FERC Order 845 and 2023 to improve decision making
- Facilitate screening, optimal siting, and **automation**
- Enhance equitable outcomes by **enabling benchmarking, tracking, and auditing** of processes and reform performance

Goal #2: Improve Process and Timeline

- Backlogs and delays result of **rapid growth in requests** and ineffective management
- Balance tradeoff between **quantity of projects and maintaining competition**
- Provide **interconnection opportunities** for all

Key focus areas

- Queue Management
- Affected System Studies
- Inclusive and fair process
- Workforce Development

Goal #3: Promote Economic Efficiency

- Acknowledge that **interconnection and transmission planning** are closely related
- Focus on both **allocative efficiency** ('who pays') and **productive efficiency** ('minimizing costs')

Key focus areas

- Cost Allocation
- Planning Coordination
- Interconnection Studies

Goal #4: Maintain a Reliable, Resilient, and Secure Grid

- In recent years, there has been **a series of disturbance events** leading to IBR disconnection
- Foundation to manage **high penetration rates of IBRs** and minimize disturbances

Key focus areas

- Interconnection Models and Tools
- Interconnection Standards

Sample Roadmap Solution: Data Transparency

Solution 1.3: Develop tools to manage, analyze, and visualize transmission and interconnection data made available in first two solutions (medium-term)

- Support Goal #1 – increase data access and transparency
- Expand and Harmonize tools. Example, add dynamic stability.
- Increase data visualization

Actor	Engineering and Technical	Market and Regulatory	Administrative and Organizational
Transmission providers	<ul style="list-style-type: none"> - Develop and support development of visualization tools - Develop, test and deploy systems to ensure data used in visualizations are up-to-date 	<ul style="list-style-type: none"> - Comply with requirements for visualization tools 	<ul style="list-style-type: none"> - Convene stakeholders
Interconnection customers		<ul style="list-style-type: none"> - Propose additional visualization tools and metrics 	
Software vendors	<ul style="list-style-type: none"> - Develop visualization software, giving due consideration to CEII concerns - Develop tools and systems to ensure models and data are up-to-date 		
Research community (including DOE)	<ul style="list-style-type: none"> - Support software development 	<ul style="list-style-type: none"> - Propose additional visualization tools and metrics 	

Sample Roadmap Solution: Queue Management

Solution 2.3: Continue to automate parts of the interconnection process, such as data input and validation, some customer communications, and data sharing across processes and models (short-term)

- Support Goal #2 - improve process and timeline
- Automation should facilitate transparency and accountability to study timelines
- Some pilots are underway across the U.S. but opportunities to expand

Actor	Engineering and Technical	Market and Regulatory	Administrative and Organizational
Federal entities		- Identify opportunities for federal funding for automation	
FERC		- Encourage transmission providers to identify opportunities for automation	
Transmission providers	- Identify needs and priority areas for automation	- Identify opportunities for federal funding for automation	
Interconnection customers			- Provide feedback to transmission providers and FERC on priority areas for automation
Research community (including DOE)	- Support software development for automation	- Document needs and priority areas for automation	
Software vendors	- Develop and tailor queue software that automates queue functions		

Sample Roadmap Solution: Interconnection Studies

Solution 3.5 Evaluate all effective mitigation options during interconnection studies, incorporating alternative transmission technologies as well as control options for IBRs (short-term)

- Support Goal #3 – Promote economic efficiency
- These technological strategies should better help right size the transmission grid, reducing customer costs

Actor	Engineering and Technical	Market and Regulatory	Administrative and Organizational
FERC	- Evaluate other emerging solutions beyond those included in Order 2023	- Updating list of alternative technologies - Develop incentive models to encourage alternative technologies	
Transmission providers, Transmission owners	- Evaluate all effective mitigation options during interconnection studies -Identify technology that accelerates process - Keep up-to-date models	- Engage with market participants and vendors to ensure accurate technology and cost information for all mitigation solutions	- Engage stakeholders to develop and publish a comprehensive set of mitigation solutions
Interconnection customers	- Evaluate viability of grid forming controls and provide alternative site-specific grid forming plant model to transmission provider		- Provide necessary data and modeling information to enable assessment of advanced IBR controls as mitigation options
Research community (Including DOE)	- Evaluate emerging mitigation solutions - Develop effective screening methods for evaluating and comparing mitigation solutions -Develop models for emerging technologies		- Inform FERC and other stakeholders on new technology mitigation options
Software vendors	- Develop and adapt software to capture and incorporate GETs		

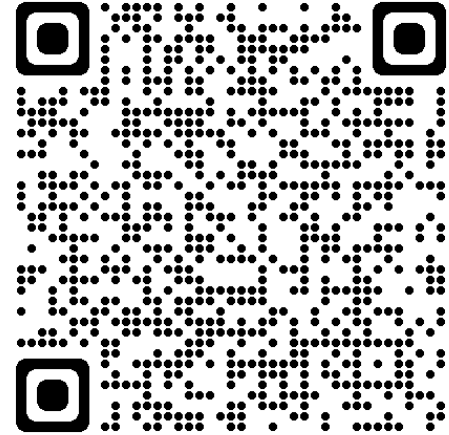
Sample Roadmap Solution: IBR Models and Tools

Solution 4.1 Require submission of verified EMT models for all IBRs during the interconnection process, ahead of EMT studies being needed, and develop screening criteria to determine when EMT studies are necessary within a region (short-term)

- Support Goal #4 – Maintain a reliable, resilient, and secure grid

Actor	Engineering and Technical	Market and Regulatory	Administrative and Organizational
FERC		-Consider requiring collection of EMT models	
NERC	-Continue to provide guidance on EMT modeling/studies -Include EMT modeling and study requirements in NERC standards		
Transmission provider	-Investigate when RMS tools/models can be extended -Develop screening tools to understand when EMT studies are needed		-Collect EMT models for new and certain legacy IBRs
Interconnection customers and their equipment manufacturers	-Develop validated new and legacy site-specific plant EMT models -Conduct EMT model assessment before submission -Develop and validate equipment models in EMT -Produce site-specific EMT models for IBR plants. -Enhance RMS plant models to extend validity of RMS study results.		
Research community (including DOE)	-Develop screening methods to understand when EMT study is needed. -Develop further enhancements of RMS models. -Improve computational efficiency of EMT studies		

Next Steps for implementing the Roadmap



Funding research and technical assistance

FOA 3246: Solar and Wind Interconnection for Future Transmission

- Topic Area 1: Improved Efficiency of EMT Simulations for Interconnection Studies of IBRs
- Topic Area 2: Dynamic Stability-Enhanced Network Assessment Tools



Roadmap stakeholder engagements



Topical deep dive convenings

Coming Soon: Standards –LBNL/ESIG dissemination and facilitation of adoption with shared learnings

Join . Engage . Collaborate

Questions?

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