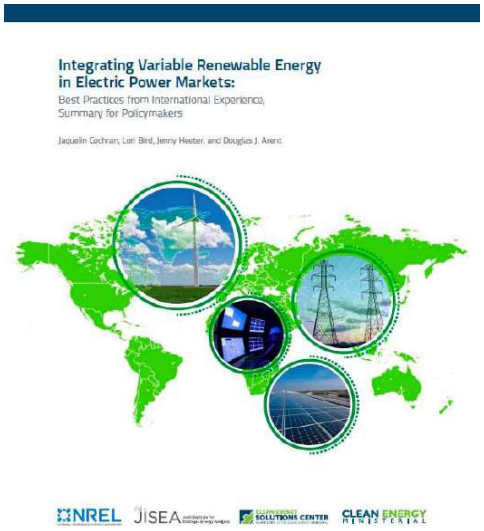
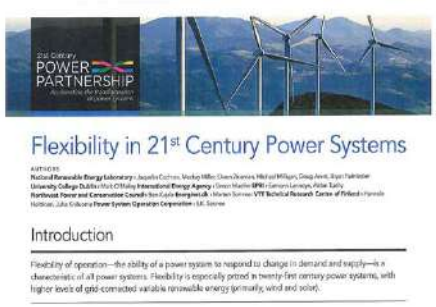
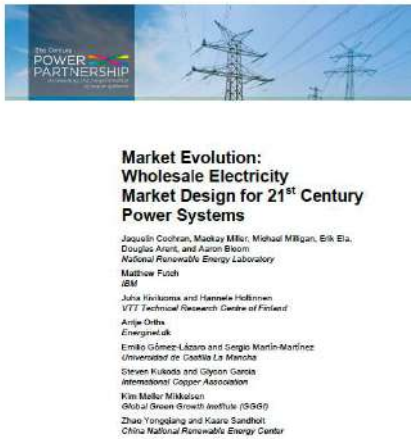
Best Practices for Integrating Renewables: Power System Transformation Approaches

Dr. Douglas J. Arent
Deputy Assoc. Lab Director
Scientific Computing and Energy Analysis
November 2019
REI
Tokyo, Japan

FOUNDATIONAL PUBLICATIONS:
FLEXIBILITY IN POWER SYSTEM TRANSFORMATION







CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

Brazil (co-lead) | **China** | **India** (co-lead) | **Denmark** | **Finland** | **Mexico** (co-lead) | **South Africa** | **Spain** | **United States** (co-lead, under review)

Leading Transformation: A System-wide Approach

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

Brazil (co-lead) | **China** | **India** (co-lead) | **Denmark** | **Finland** | **Mexico** (co-lead) | **South Africa** | **Spain** | **United States** (co-lead, under review)

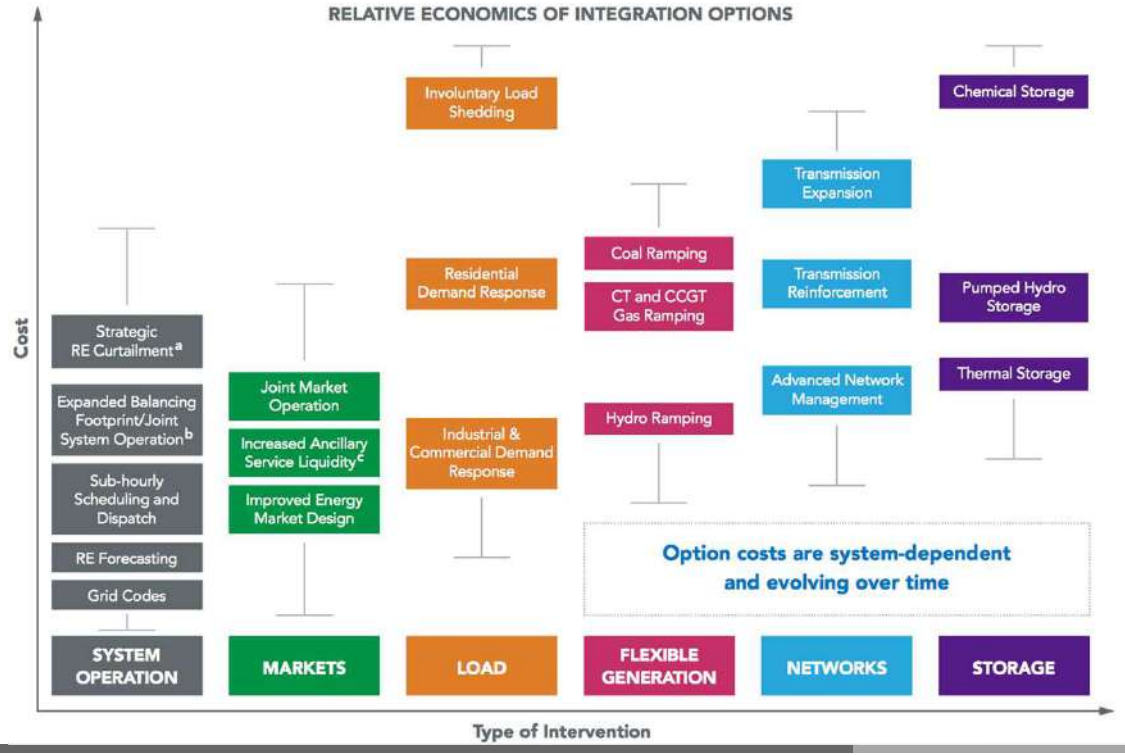
ACTIONS REFLECT MARKET STATUS

	Public Outreach	Planning	Market Rules	Expanded Access	System Operations
At LOW RE Penetrations	Involve public stakeholders in planning	Evaluate system flexibility, penetration scenarios, transmission needs, and future flexibility needs	Evaluate market design and implications for higher penetrations of RE	Assess renewable energy resources and options for encouraging geographic diversity	Build capacity of grid operator staff; review regulatory changes needed to require advanced forecasting
At MEDIUM RE Penetrations	Communicate to public why new transmission is essential	Regulatory and legislative changes needed to accommodate revised scenario planning, such as laws to support renewable energy zones (REZs)	Ensure that market design and pricing environment aligns with technical needs, such as accessing flexibility, minimizing uncertainty, and managing risk	Make necessary regulatory, market, or institutional changes	Implement grid codes to accommodate high penetrations of variable RE
At HIGH RE Penetrations		Monitor and review effectiveness of actions; revise	Make additional changes to market rules to meet technical needs, such as accessing flexibility, minimizing uncertainty, and managing risk	Ensure broad systems solutions are sought, including smart grid/demand response, storage, and complementary flexible generators	

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

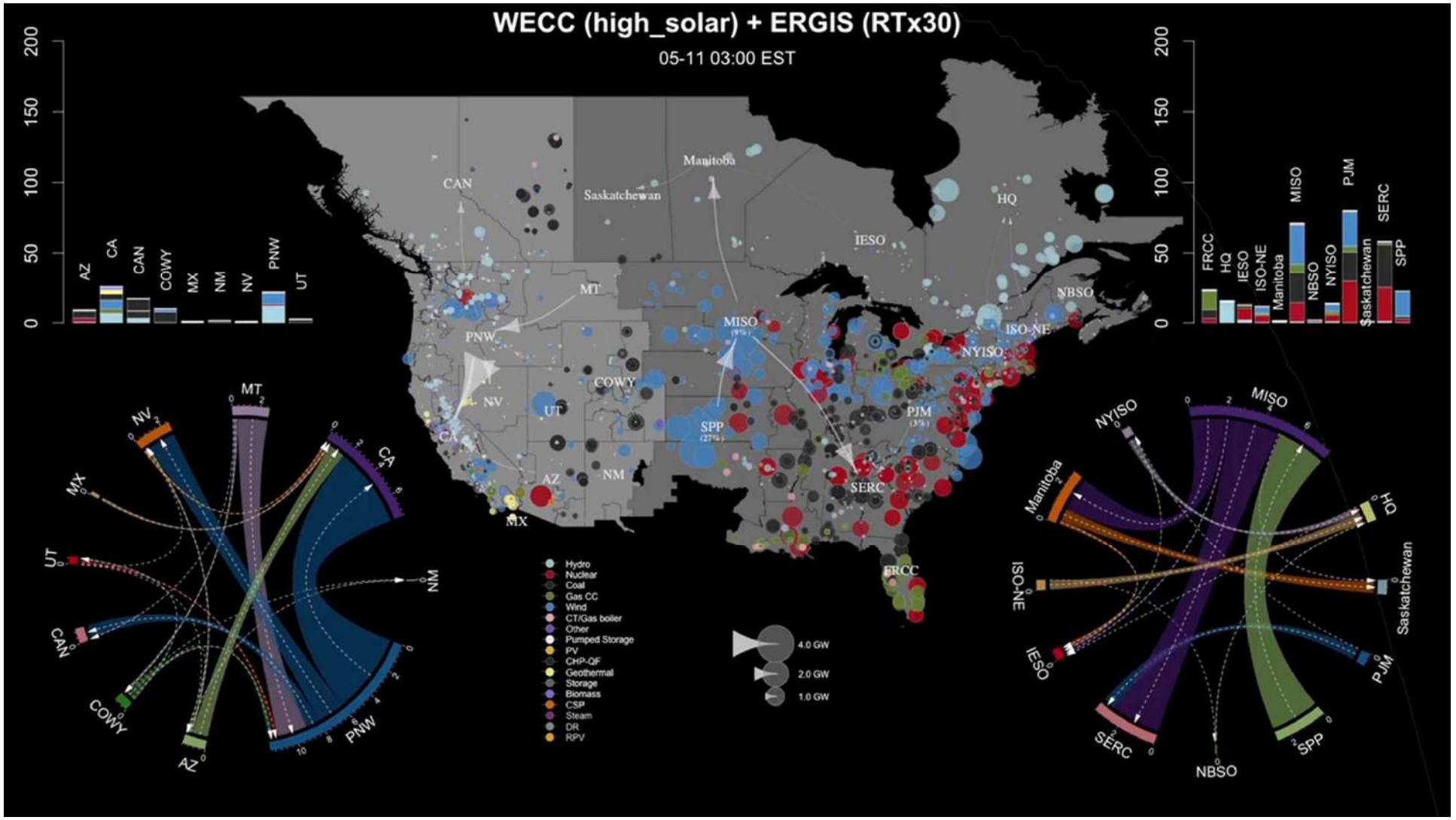
Brazil (co-lead) | **China** | **India** (co-lead) | **Denmark** | **Finland** | **Mexico** (co-lead) | **South Africa** | **Spain** | **United States** (co-lead, under review)

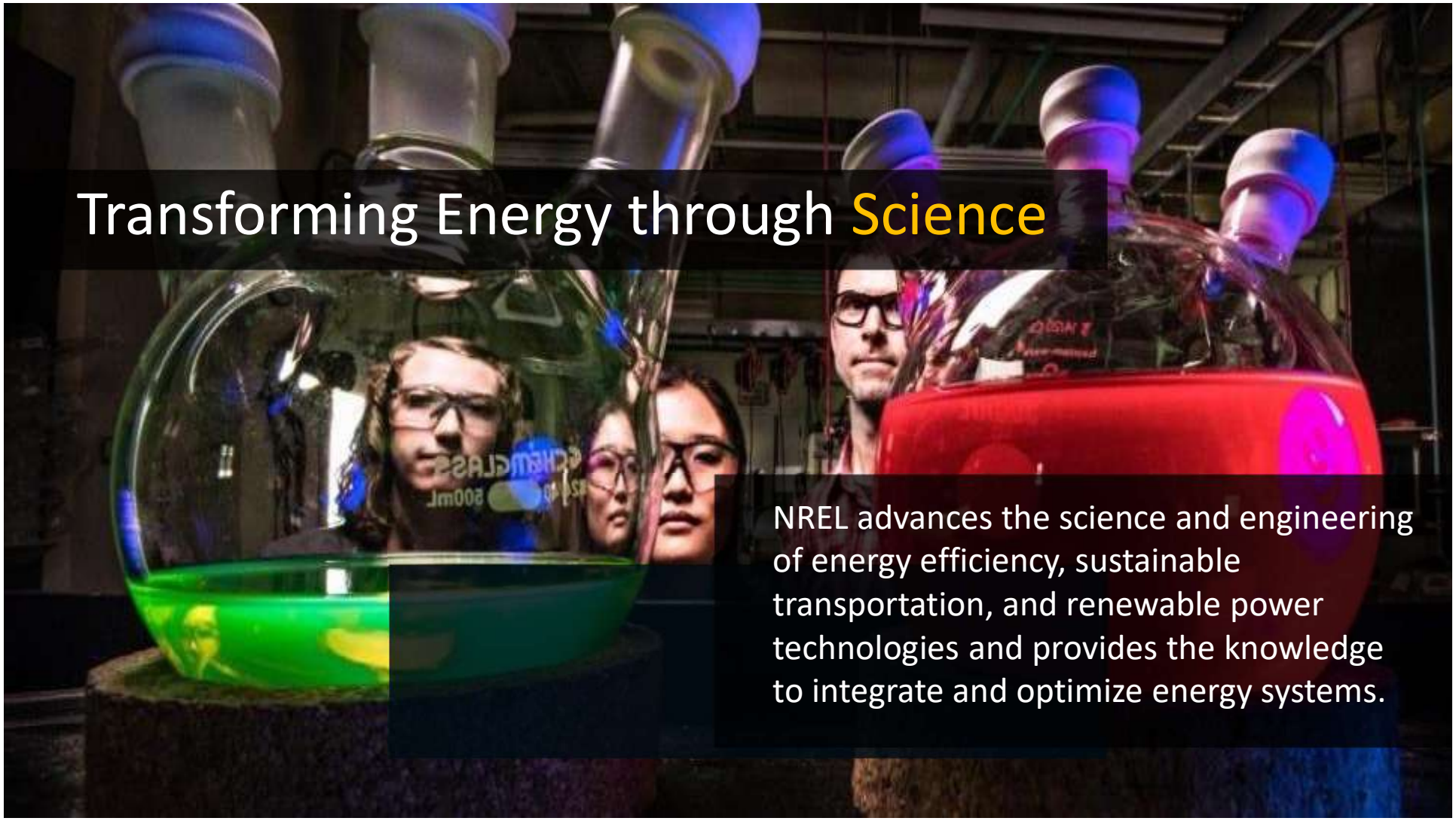
Integration Options



CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

Brazil | China | India (co-lead) | Denmark | Finland | Mexico (co-lead) | South Africa | Spain | United States (co-lead, under review)


WECC (high_solar) + ERGIS (RTx30)
05-11 03:00 EST
0
50
100
150
200
AZ
CA
CAN
COWY
MX
NM
NV
PNW
UT
FRCC
HQ
IESO
ISO-NE
Manitoba
MISO
NBSO
NYISO
PJM
Saskatchewan
SERC
SPP
CAN
Saskatchewan
Manitoba
HQ
IESO
MT
PNW
MISO
(9%)
NBSO
ISO-NE
NYISO
COWY
NV
UT
SPP
(27%)
PJM
(3%)
CA
AZ
NM
SERC
MX
FRCC
Hydro
Nuclear
Coal
Gas CC
Wind
CT/Gas boiler
Other
Pumped Storage
PV
CHP-QF
Geothermal
Storage
Biomass
CSP
Steam
DR
RPV
4.0 GW
2.0 GW
1.0 GW


Transforming Energy through Science
NREL advances the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems.