2 JUNE 2018

ARGONNE'S ADVANCED ANALYTICS FOR RENEWABLE ENERGY SYSTEM PLANNING

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Argonne NATIONAL LABORATORY

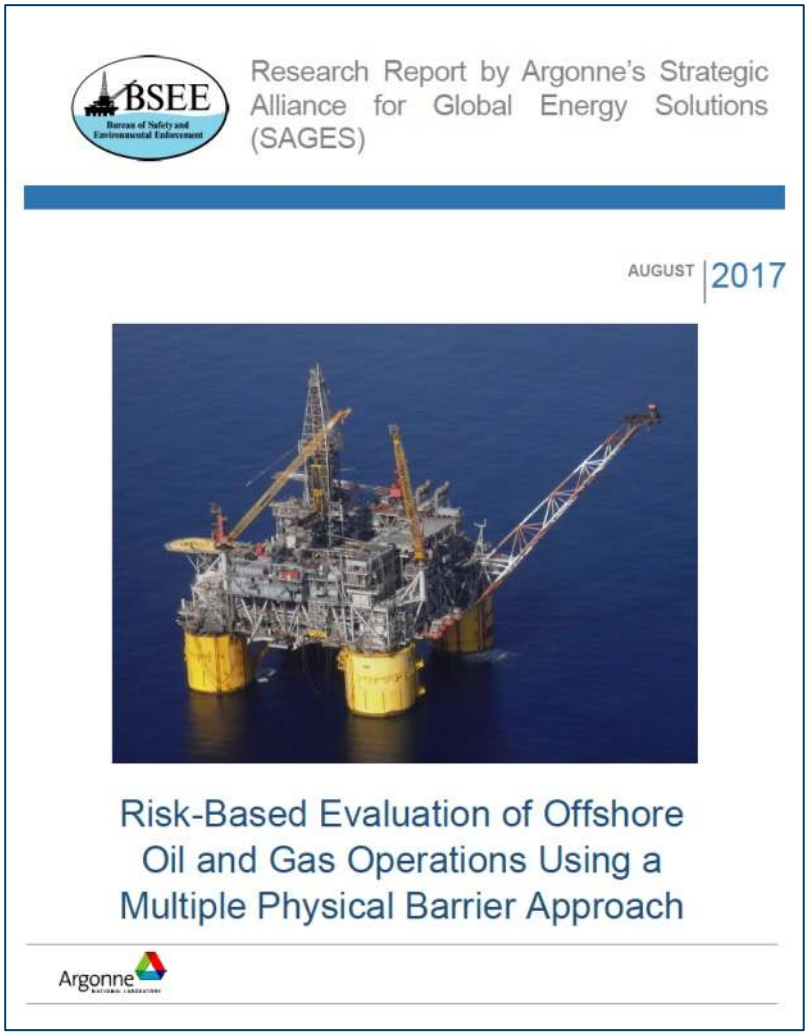
PRESENTATION OUTLINE

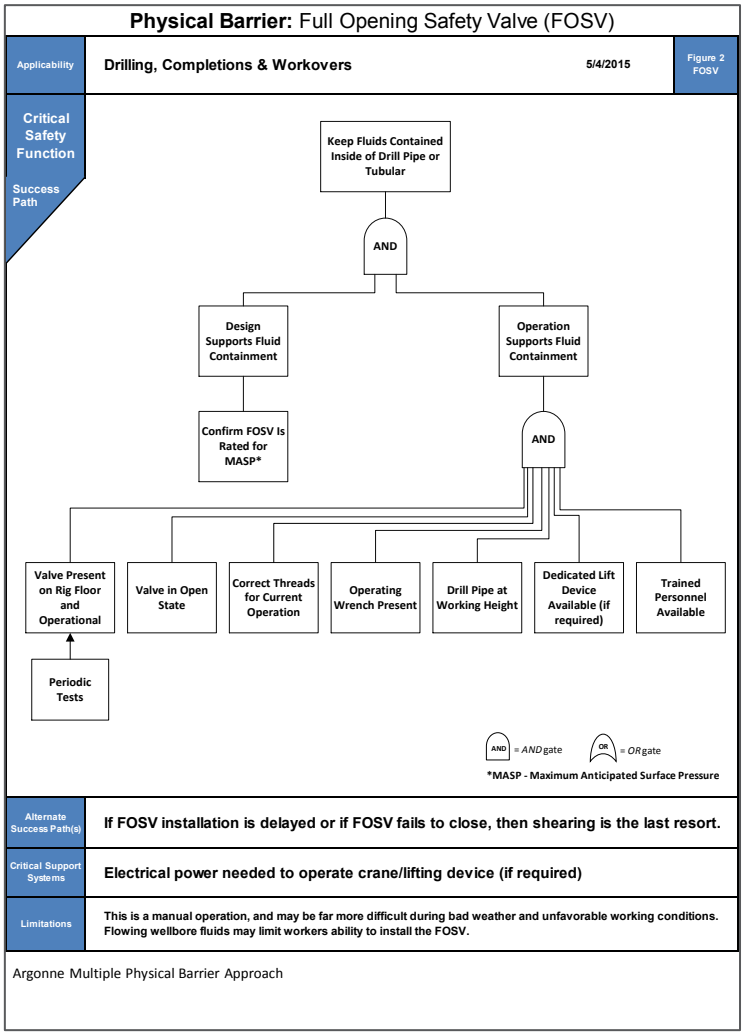
1. Intro to Global Energy Solutions
2. ADB National Planning Support
3. ADB Regional Planning Support
4. Additional Areas of Support
   - Energy Market Modeling and RE Integration
   - Institutional Capacity Building for Improved Energy System Resiliency
   - Transportation System Planning
   - Technology Business Case Evaluation


Energy Systems Division
U.S. EV-Smart Grid
Interoperability Center
CEEESA
Global Energy Solutions
Advanced Photon
Source (APS)
Joint Center for Energy
Storage Research (JCESR)
Argonne Leadership
Computing Facility (ALCF)
Argonne National Laboratory

GLOBAL ENERGY SOLUTIONS FOCUS AREAS

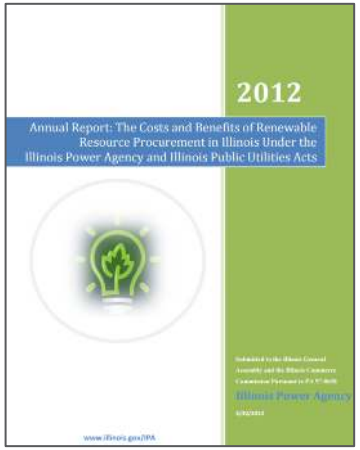
RISK INFORMED DECISION MAKING

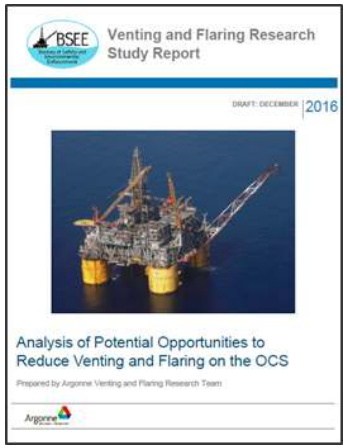




Argonne Multiple Physical Barrier Approach

POLICY IMPACT ASSESSMENT AND ECONOMIC ANALYSIS





Cost-Benefit Analysis of State and Federal Energy Policy

National Power Master Plans

Infrastructure Transformation

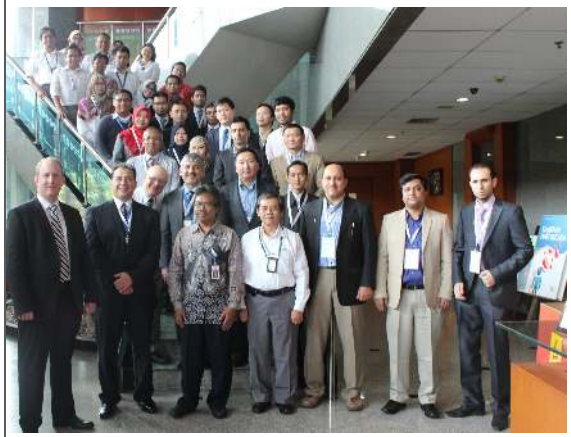

ASIAN DEVELOPMENT BANK

TA-8830 REG: Harmonizing the Greater Mekong Subregion Power Systems to Facilitate Regional Power Trade

Report No. 2 on

PROPOSED GMS PERFORMANCE STANDARDS

Prepared by
Bruce P. Hamilton



Regional Interconnection and Energy Trade

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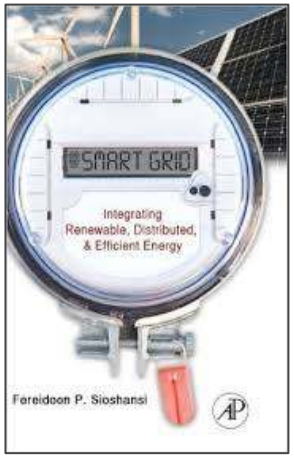
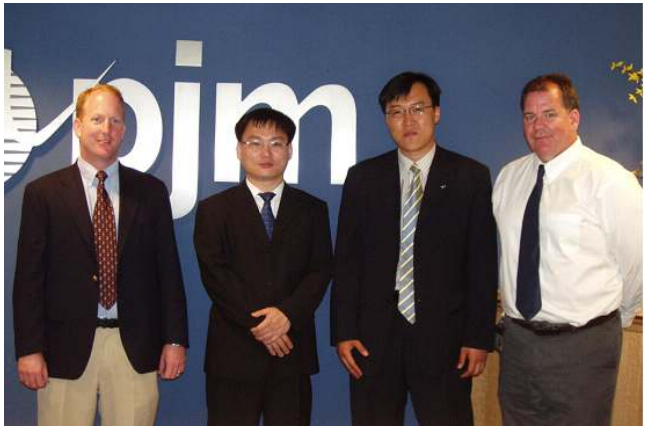
TECHNICAL ASSISTANCE

Regional Training Course on Evaluation of Cost-effective Energy Technologies, Including Nuclear Power, as NDCs for Climate Change Mitigation
IAEA / Argonne Training Course





Research, Evaluation and Identification of International Best Practices

Generation-Transmission-Distribution Planning

Institutional Capacity Building

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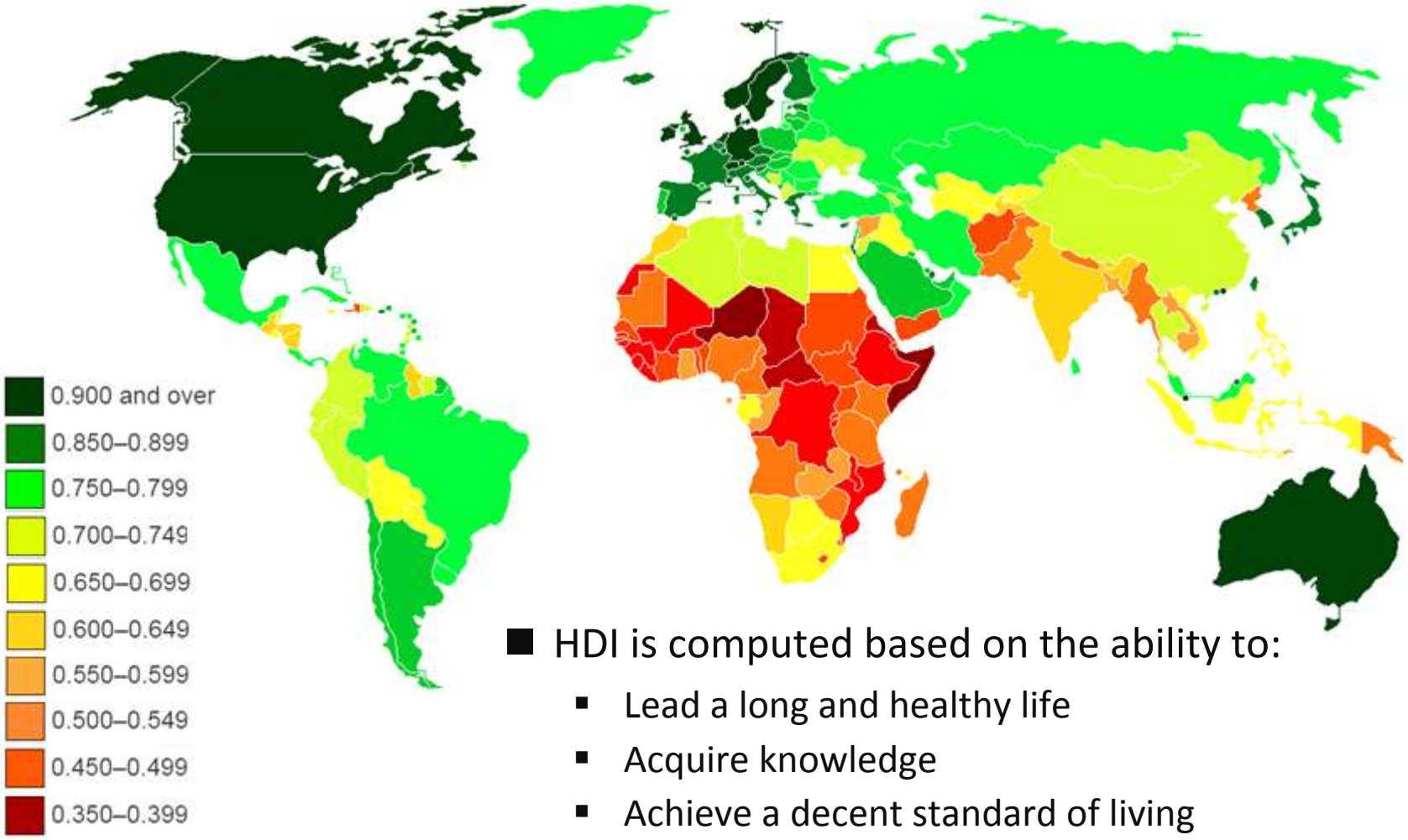
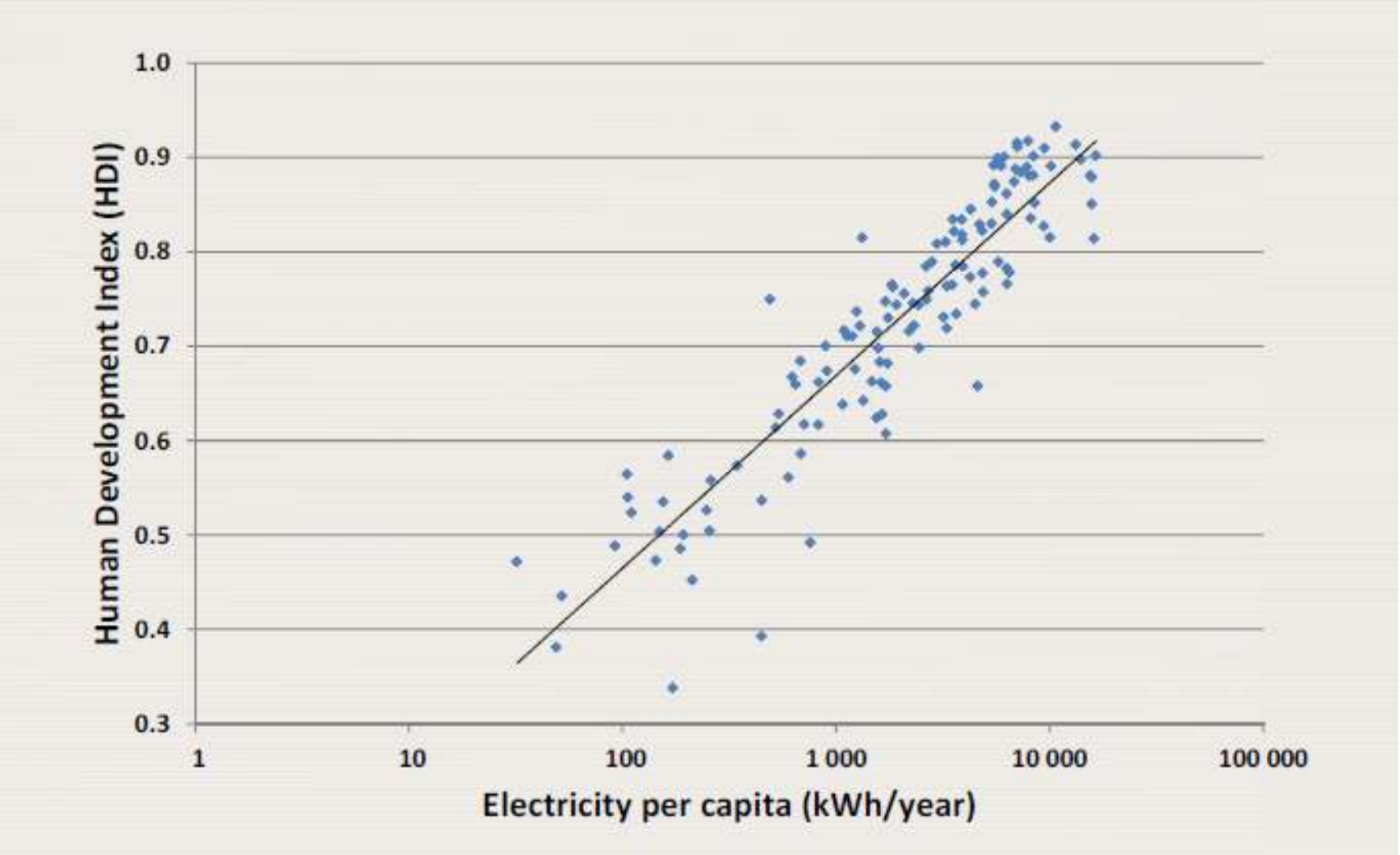
Human Development Index



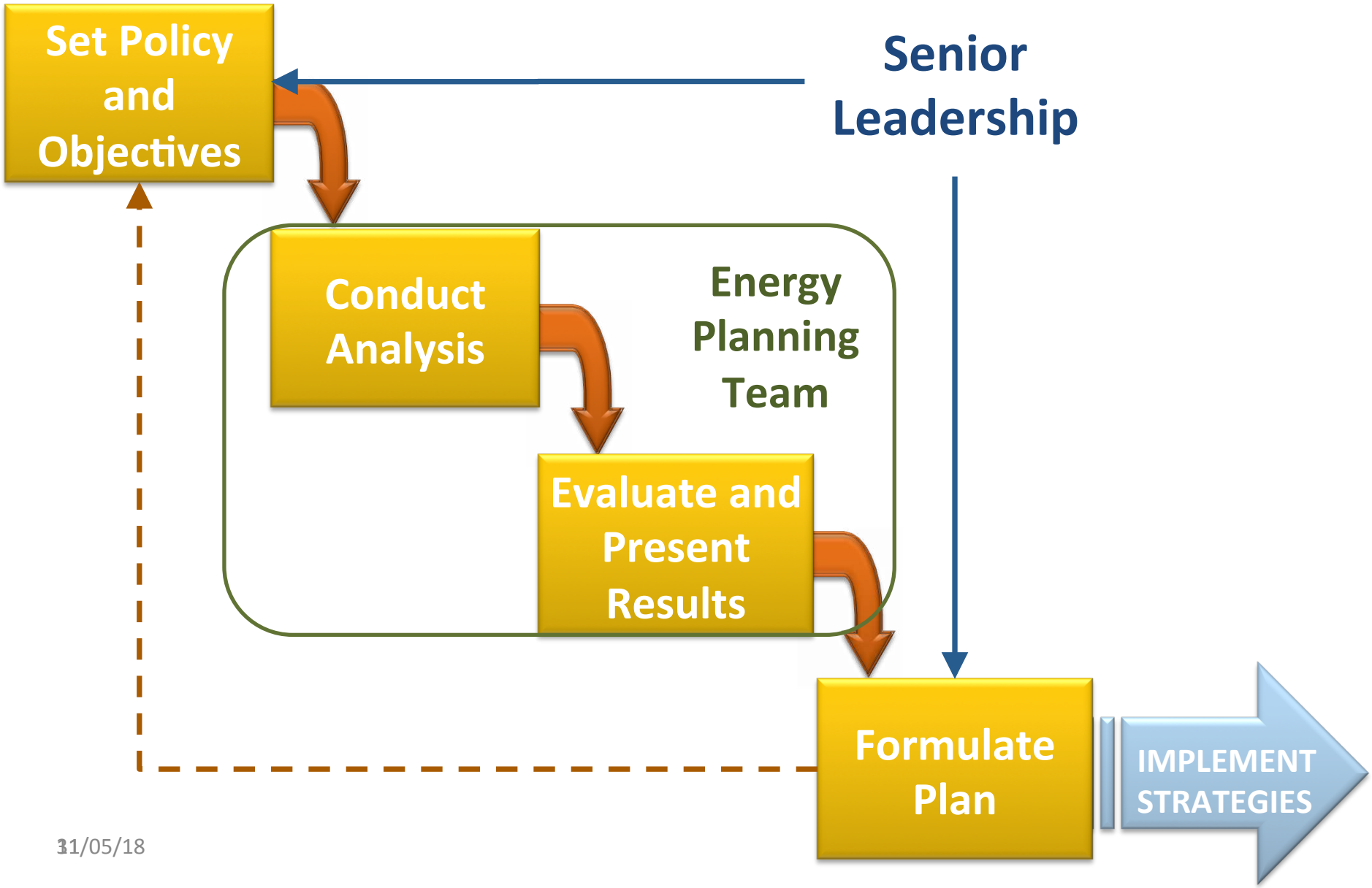
- HDI is computed based on the ability to:
  - Lead a long and healthy life
  - Acquire knowledge
  - Achieve a decent standard of living

Source: 2015 UNDP Human Development Report

Energy is a key input for socio-economic development



ENERGY PLANNING PROCESS

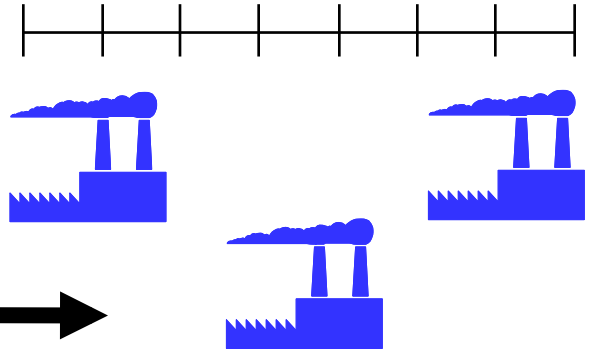


WASP
Power System Planning Tool

INPUT

- Load forecast
- Existing system
- Candidates
- Constraints:
  - Reliability
  - Implementation
  - Fuel
  - *Generation*
  - *Emissions*

OUTPUT



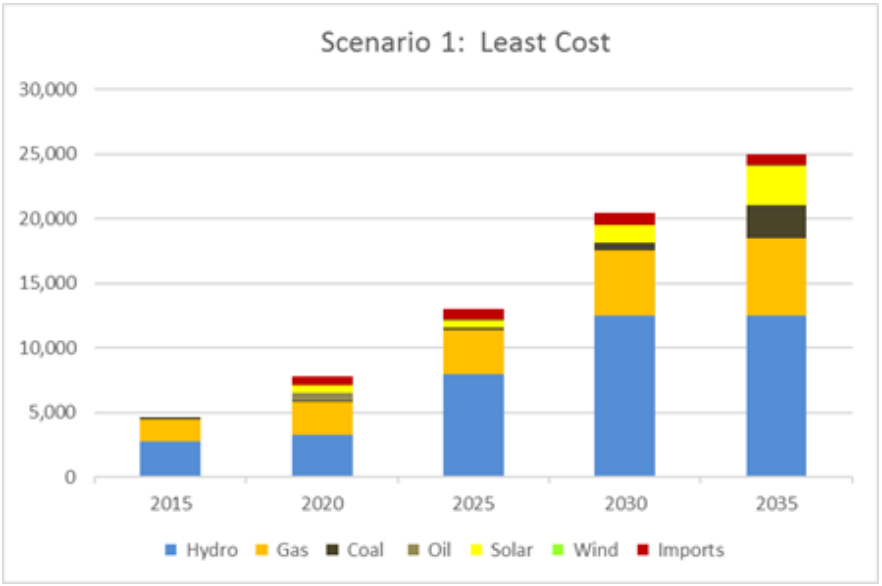
- Build schedule
- Generation
- Costs
- Fuel consumption
- *Emissions*

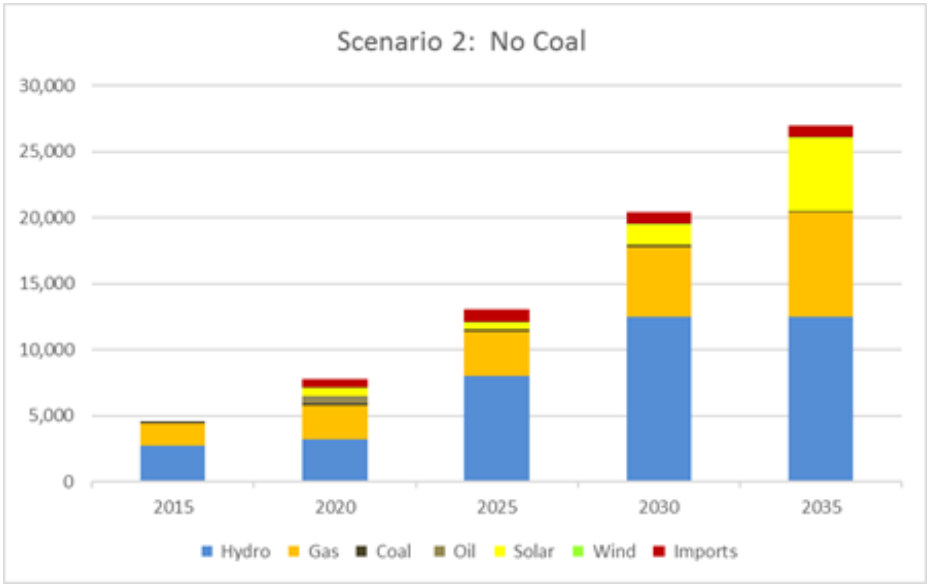
IAEA distributes WASP for use in over 107 countries and 12 international agencies

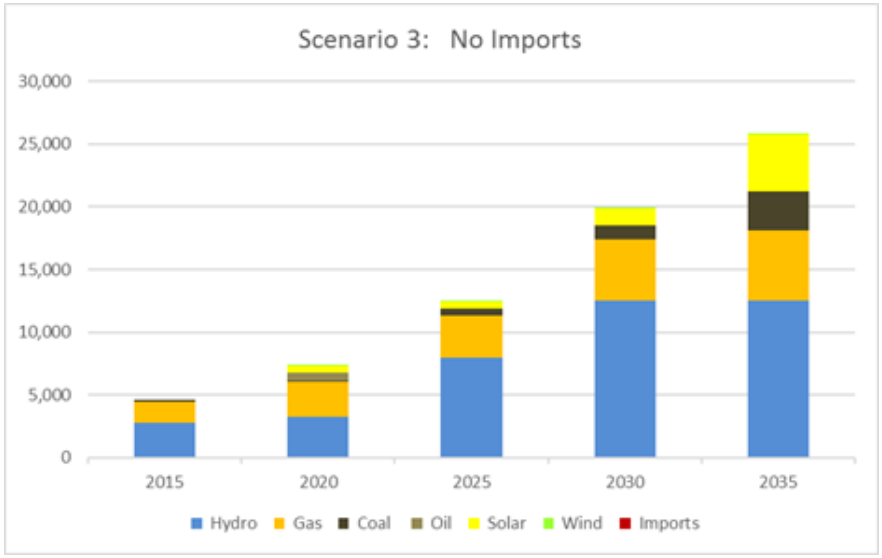
Training on Generation Expansion Planning with WASP

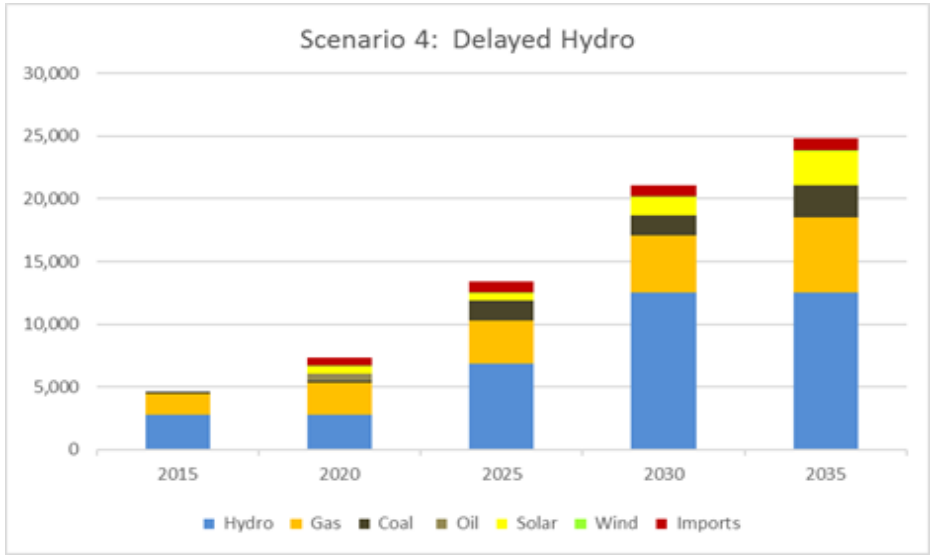
ADB WASP Training held at MOEE

Analysis of Alternative Futures









Scenario Comparison

GOALS	Key Performance Indicators	Units	Least Cost	No Coal	No Import	Delayed Hydro
Sustainable	CO2 Emissions	M tonnes	147	127	185	224
	Renewables in 2035	%	12%	21%	18%	11%
Reliability	Average LOLP	hour / yea	7.5	8.5	8.5	8.7
Competitive	Total cost	billion $	20.19	20.25	20.85	22.88
	Foreign fuel bill	billion $	16.1	17.5	14.9	21.9

Best 2nd best 2nd worst Worst

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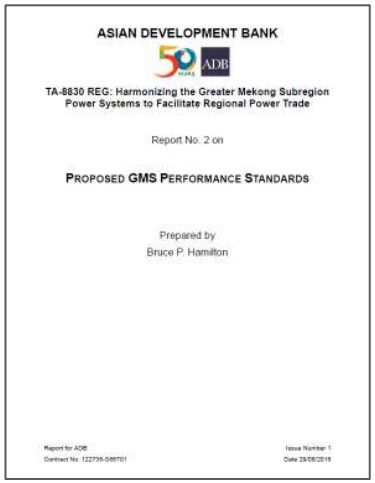
ARGONNE SUPPORT FOR REGIONAL PLANNING FUNDED BY THE ASIAN DEVELOPMENT BANK

CAREC Power Sector Regional Master Plan

– Supported ADB project to develop integrated transmission and generation expansion plan

ADB Consultant to Greater Mekong Subregion Regional Power Trade Coordination Committee

– Defined performance standards for harmonizing GMS power systems to facilitate regional power trade
– Conducted demonstration analysis to identify timing, amount and price of mutually beneficial energy trade between Myanmar and China/Lao PDR/Thailand.


ASIAN DEVELOPMENT BANK

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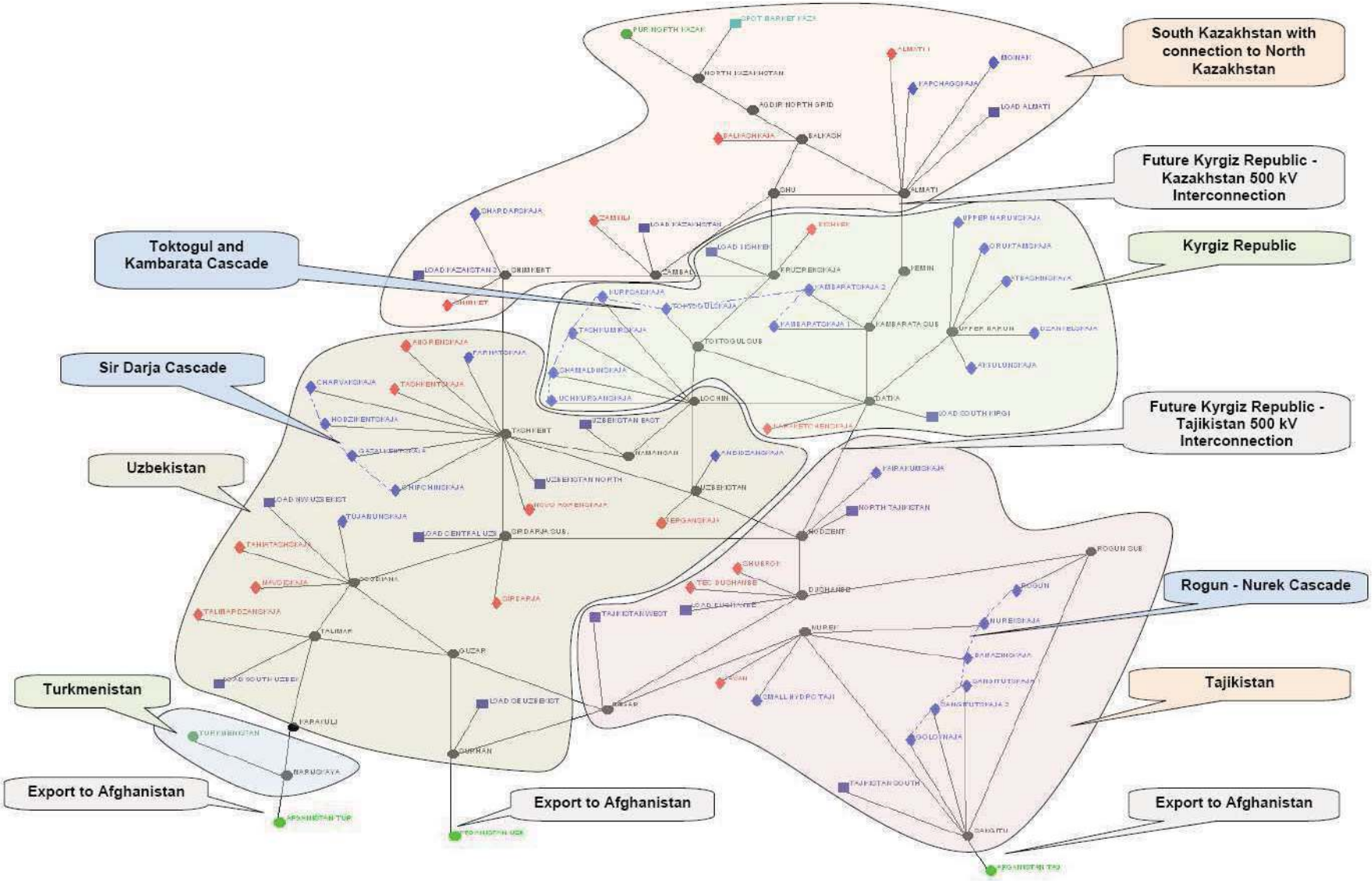
Proven Approach for Facilitating Regional Power Trade

Regional Trade Benefits from Use of A Common Analytical Framework

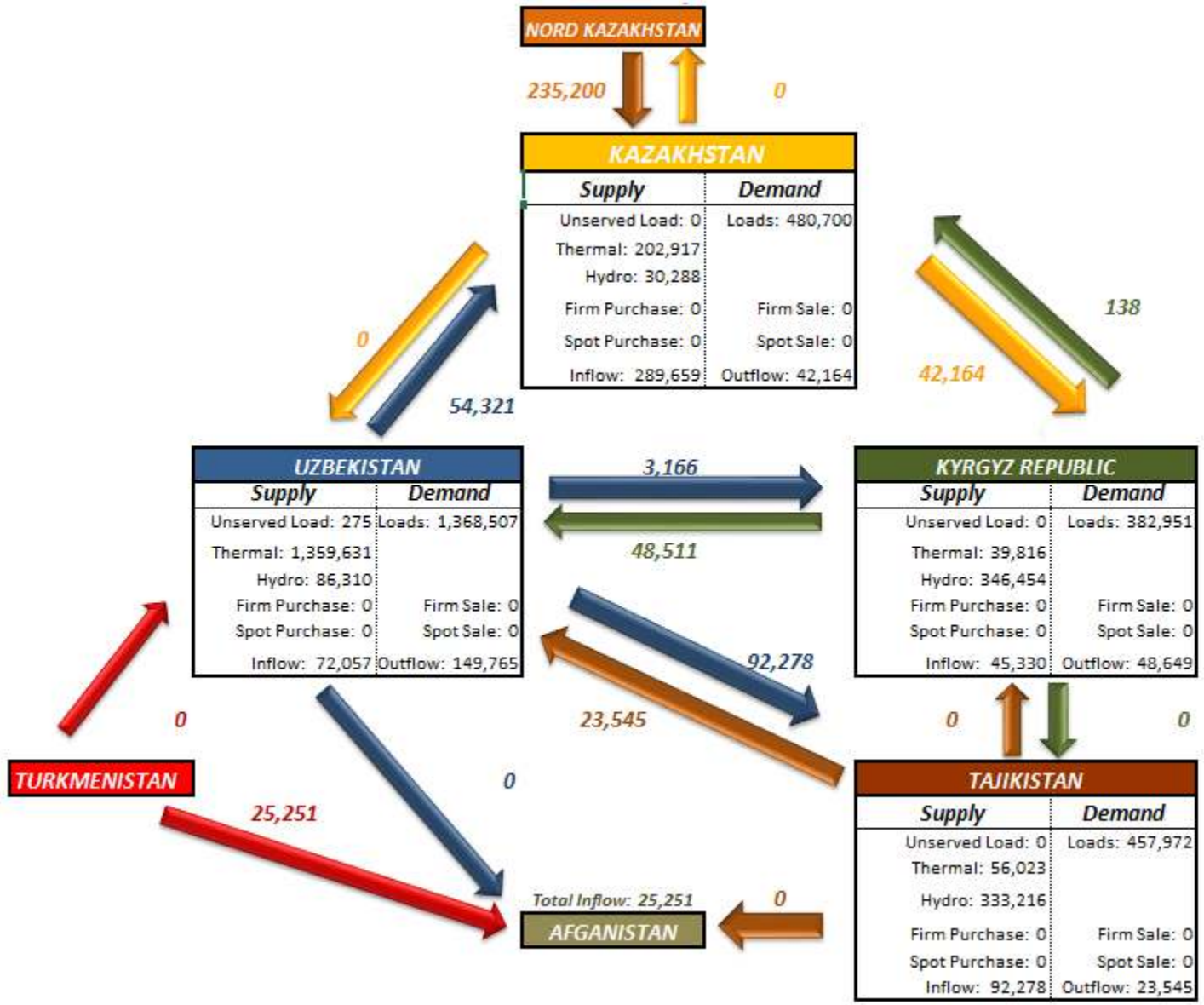
- Generation Expansion Planning
  - Prepare optimal generation expansion plans
- Generation & Transmission Planning
  - Optimize system operations taking into account power plants, hydro cascades, IPP agreements, power trading opportunities, and limitations of transmission resources
- Detailed Transmission Planning
  - Power Flow and Stability Analysis
  - Available Transmission Capacity

Use of a common analytical framework for evaluating regional energy trade builds consensus on mutually beneficial paths forward

GTMAX MODEL TOPOLOGY OF SYSTEM IN 2020



GTMAX SIMULATED POWER FLOWS



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ARGONNE ENERGY RESEARCH SERVES DIVERSE CUSTOMERS

DOE - OE
- Grid Resilience
- Smart Grid
- Micro-grid
- Cyber

DOE - EERE
- Wind
- Water
- Solar
- Buildings
- Vehicles

OTHER U.S. FEDERAL
- DOE-EPSA (Policy)
- Science – ASCR
- ARPA-E
- Bureau of Safety and Environmental Enforcement
- Department of Transportation

DHS
- Infrastructure protection
- FEMA

INDUSTRY
- Utilities
- ISOs/RTOs
- Vendors

INTERNATIONAL
- USAID, USEA
- ADB, World Bank
- UNDP, IAEA
- KPX, MKE/MOTIE

ENERGY MARKET MODELING AND RENEWABLE ENERGY INTEGRATION

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ARGONNE ENERGY RESEARCH COVERS ALL TIME DOMAINS

(SUB)SEC/MIN

- Dynamics modeling and simulation
- Transient stability
- Optimal power flow
- Cascading failures

HOURS/DAYS

- Operational modeling, unit commitment, economic dispatch, incl. stochastic modeling
- Power system restoration

YEARS

- Long-term investment dynamics
- Long-term market trends and reliability/resilience considerations for future infrastructure

ARGONNE MODELING TOOLS SUPPORT INFORMED DECISION MAKING

Grid Reliability Tools at Interconnect-Level

- DC power flow and AC power flow cascading event simulation tools
- Dynamic stability tools
- T&D co-simulation platform

Power Market Tools at Regional or Interconnect Levels

- Unit commitment/dispatch tools,
- Long-term investment tools
- Hydropower planning/operations

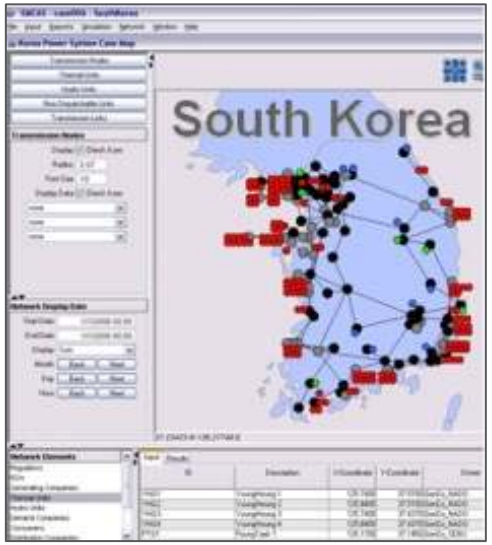
Natural Gas-Electric Analysis Tools at Regional or National Level

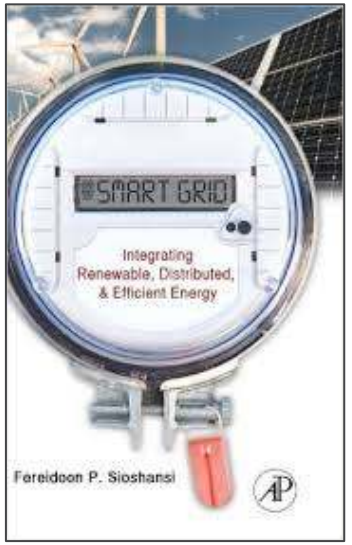
- Comprehensive gas contingency screening tool
- Real-time natural gas situational awareness tool
- Steady-state and transient hydraulic models for detailed contingency assessment

Telecommunications Tool Prototype at National Level

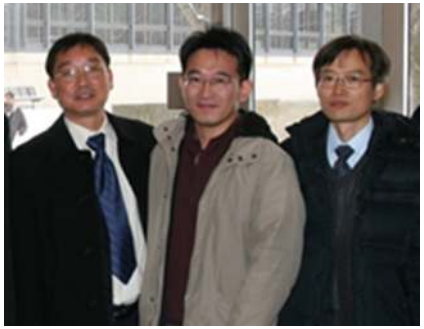
- Wireline communications
- Wireless communications
- Interdependencies with grid

MARKET MODELING, ANALYSIS AND TRAINING





Electricity Market Modeling



Argonne-IIT Joint Education Program on Electricity Markets

Training Workshops on Power System Planning

INSTITUTIONAL CAPACITY BUILDING FOR IMPROVED ENERGY SYSTEM RESILIENCY

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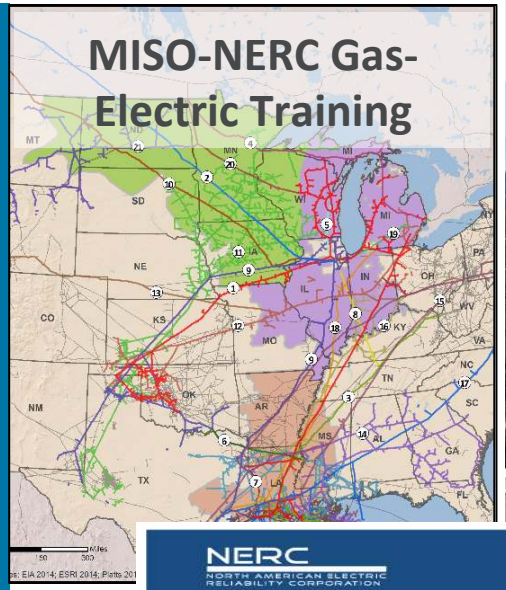
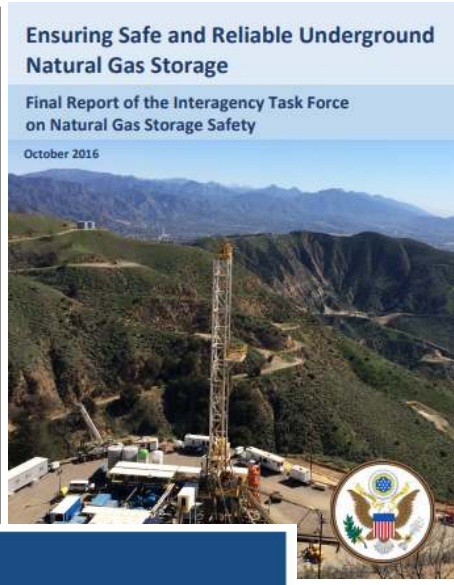
NGFAST: APPLIED IN NUMEROUS NATIONAL AND REGIONAL INDUSTRY & DOE/DHS APPLICATIONS

- Interagency Task Force report and analysis on UGS safety and reliability (10/2016)
- NERC's Single Point of Disruption Study (11/2017)
- Current WECC long-term gas-electric reliability study
- MISO and PJM gas-electric operator training
- PJM Gas-Cyber operator training
- Numerous DOE workshops and hurricane analyses
- Numerous DHS studies





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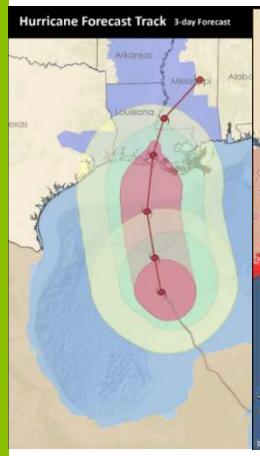
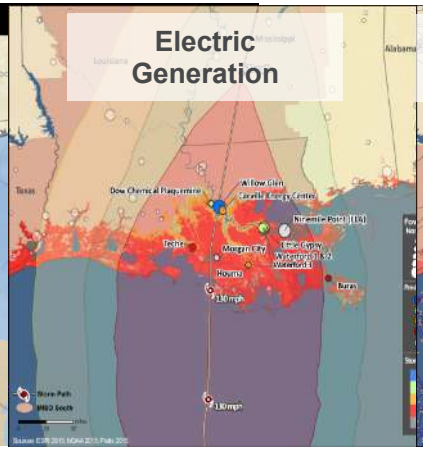
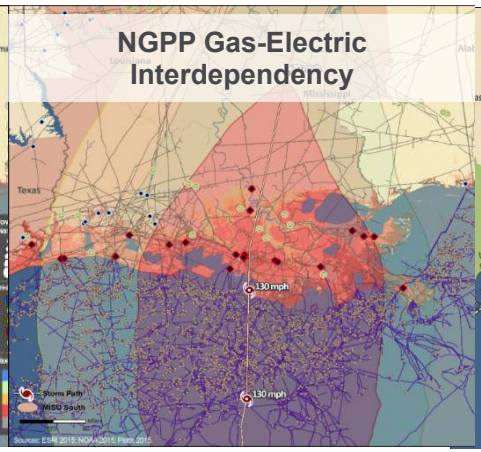
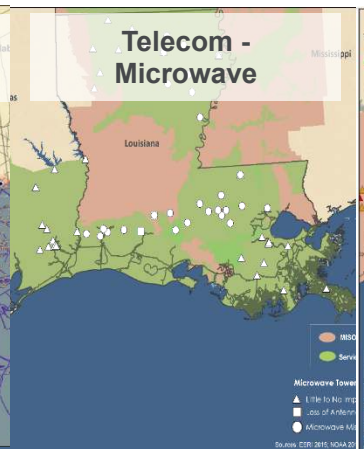
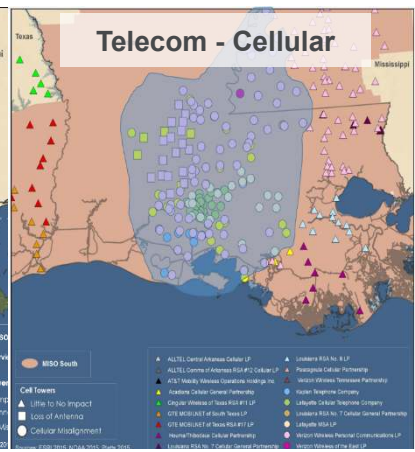
INDUSTRY SUCCESS: MISO EP/PSR OPERATOR TRAINING AND EXERCISES/DRILLS





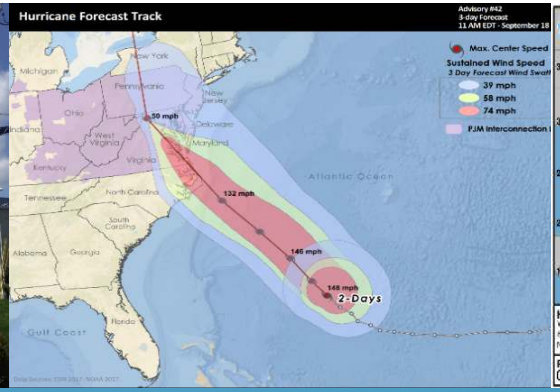


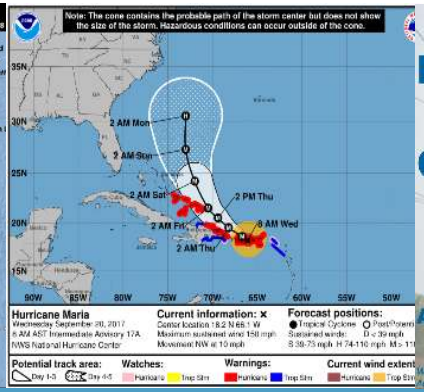




- Argonne has supported MISO's working group for Emergency Preparedness and Power System Restoration (EP/PSR) since spring 2015
- Jointly prepared 2016 and 2017 spring drills on preparedness and fall drills on response/ recovery
- Currently assisting MISO with Spring 2018 Drill (May/June) that will focus on hurricane scenario and impact on various assets, including power plants, substations, transmission assets, communications assets, and natural gas supply and natural gas processing plant impacts; will be implemented on MISO's Digital Training Simulator
- ***"The information looks comprehensive, detailed and complete."*** Jerry Rusin, Sr. Advisor MISO South Region Operations

INDUSTRY SUCCESS: PJM EP/PSR OPERATOR TRAINING AND EXERCISES/DRILLS





- Developed hurricane scenario (ironically named Maria) for October 2017 PJM Operator Training cycle
- Scenario was implemented in PJM's Digital Training Simulator (DTS) at Alternate Control Room Facility
- Trained 6 full PJM operator shifts in responding to extreme weather event during Sep/Oct-2017 ***("I thought the simulation was great and gave the operators a glimpse of what operations in a hurricane might look like. Most will never experience this in their career, but this simulation provided that opportunity." Glen Boyle, Manager, Operator Training)***
- Also developed a Gas-Cyber Scenario which PJM implemented on its DTS and was recently used in the Jan/ Feb-2018 6-week operator training cycle
- PJM plans to make this a recurring operator training session supplemented with other large-scale threat scenarios to be developed in 2018

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TRANSPORTATION SYSTEM PLANNING

HTTP://GREET.ES.ANL.GOV

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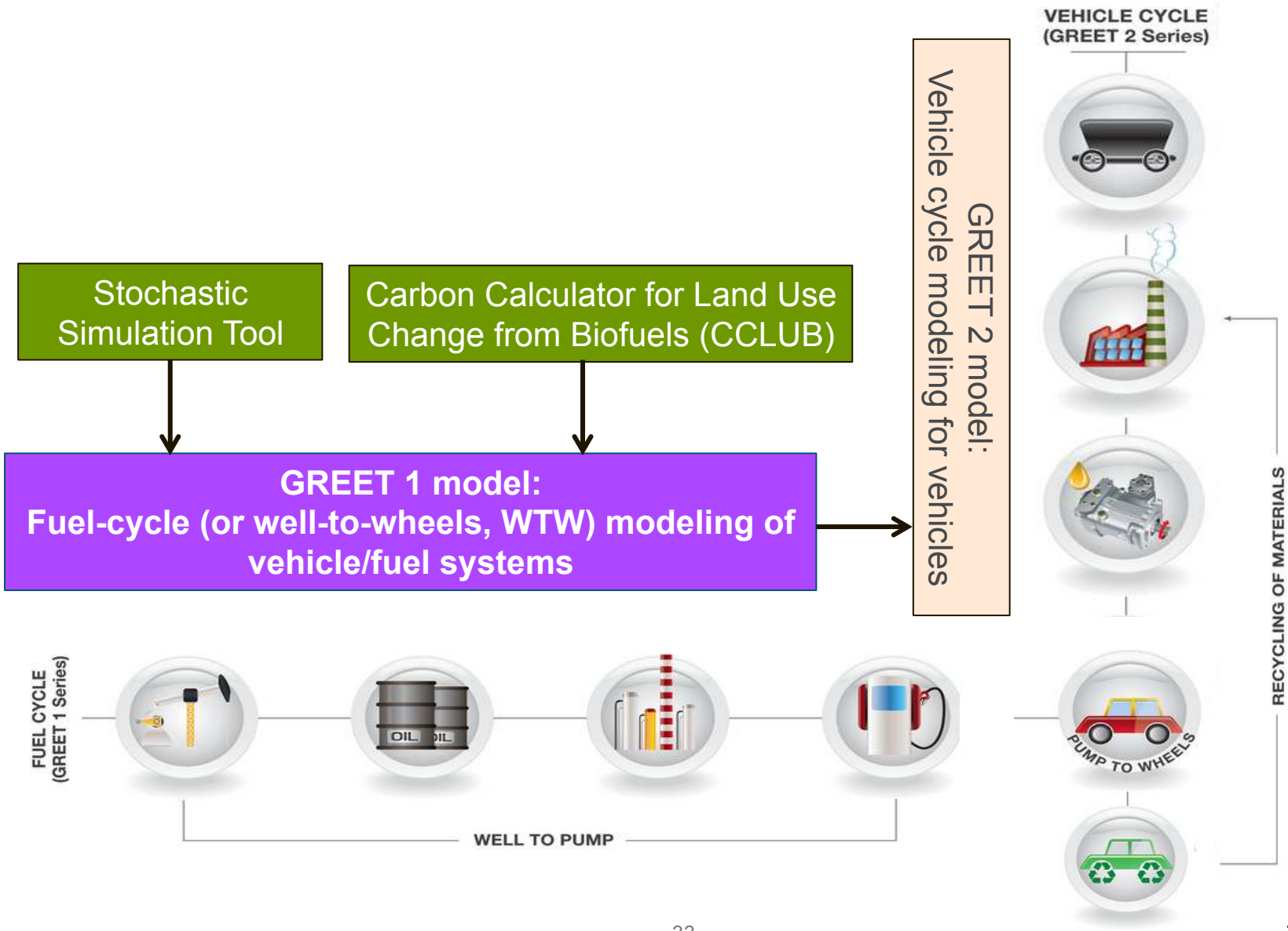
The GREET® (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) model



GREET Includes All Transportation Subsectors

- Light-duty vehicles
- Medium-duty vehicles
- Heavy-duty vehicles
- Various powertrains:
  Internal Combustion Engines
  Electrics
  Fuel cells

Road transportation

Air transportation

- Globally, a fast growing sector with GHG reduction pressure
- Interest by DOD, ICAO, FAA, and commercial airlines
- GREET includes
  - ✓ Passenger and freight transportation
  - ✓ Various alternative fuels blended with petroleum jet fuels

Rail transportation

- Interest by FRA, railroad companies
- Potential for CNG/LNG to displace diesel

Marine transportation

- Desire to control air pollution in ports globally
- Interest by EPA, local governments, IMO
- GREET includes
  - ✓ Ocean and inland water transportation
  - ✓ Baseline diesel and alternative marine fuels

GREET examines more than 80 on-road vehicle/fuel systems for both LDVs and HDVs

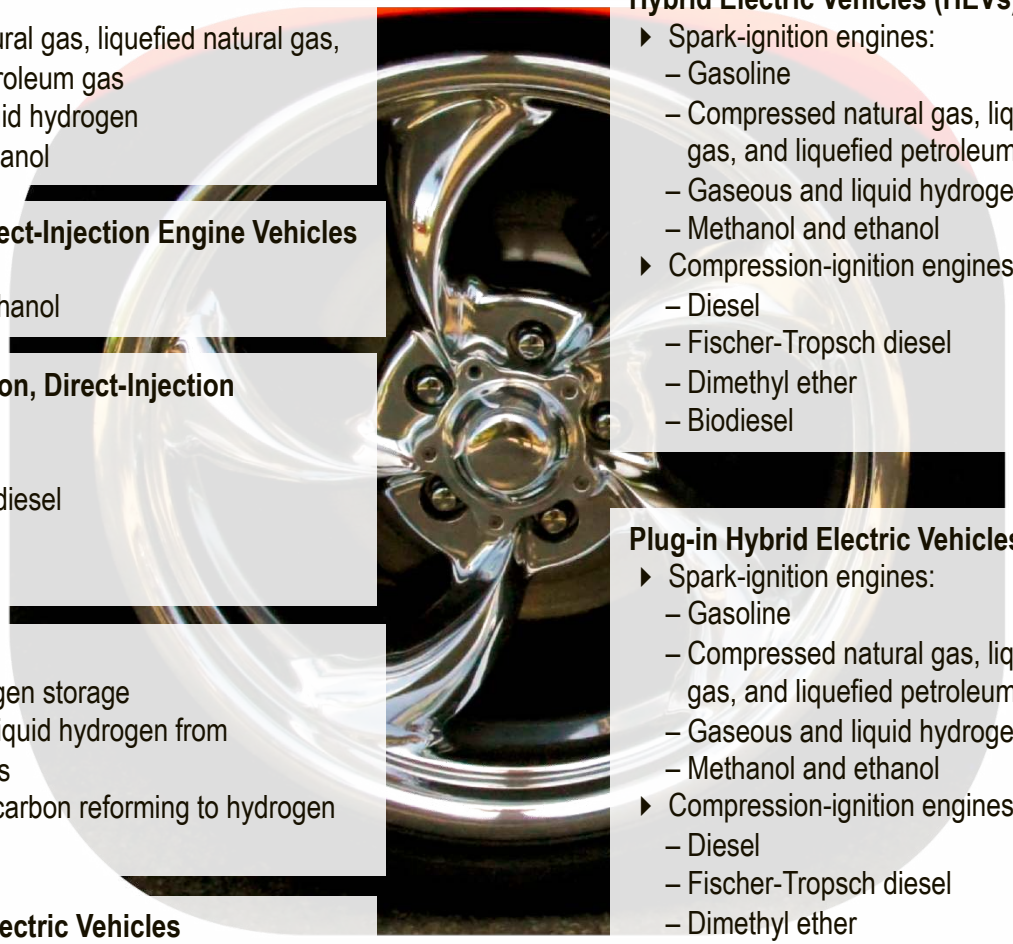
Conventional Spark-Ignition Engine Vehicles
- Gasoline
- Compressed natural gas, liquefied natural gas, and liquefied petroleum gas
- Gaseous and liquid hydrogen
- Methanol and ethanol

Spark-Ignition, Direct-Injection Engine Vehicles
- Gasoline
- Methanol and ethanol

Compression-Ignition, Direct-Injection Engine Vehicles
- Diesel
- Fischer-Tropsch diesel
- Dimethyl ether
- Biodiesel

Fuel Cell Vehicles
- On-board hydrogen storage
  - Gaseous and liquid hydrogen from various sources
- On-board hydrocarbon reforming to hydrogen

Battery-Powered Electric Vehicles
- Various electricity generation sources



Hybrid Electric Vehicles (HEVs)
- Spark-ignition engines:
  - Gasoline
  - Compressed natural gas, liquefied natural gas, and liquefied petroleum gas
  - Gaseous and liquid hydrogen
  - Methanol and ethanol
- Compression-ignition engines
  - Diesel
  - Fischer-Tropsch diesel
  - Dimethyl ether
  - Biodiesel

Plug-in Hybrid Electric Vehicles (PHEVs)
- Spark-ignition engines:
  - Gasoline
  - Compressed natural gas, liquefied natural gas, and liquefied petroleum gas
  - Gaseous and liquid hydrogen
  - Methanol and ethanol
- Compression-ignition engines
  - Diesel
  - Fischer-Tropsch diesel
  - Dimethyl ether
  - Biodiesel

GREET outputs include energy use, greenhouse gases, criteria pollutants and water consumption for vehicle and energy systems

- **Energy use**
  - Total energy: fossil energy and renewable energy
    - Fossil energy: petroleum, natural gas, and coal (they are estimated separately)
    - Renewable energy: biomass, nuclear energy, hydro-power, wind power, and solar energy
- **Greenhouse gases (GHGs)**
  - CO_2, CH_4, N_2O, black carbon, and albedo
  - CO_{2e} of the five (with their global warming potentials)
- **Air pollutants**
  - VOC, CO, NO_x, PM_{10}, $PM_{2.5}$, and SO_x
  - They are estimated separately for
    - Total (emissions everywhere)
    - Urban (a subset of the total)
- **Water consumption**
- **GREET LCA functional units**
  - Per service unit (e.g., mile driven, ton-mi)
  - Per unit of output (e.g., million Btu, MJ, gasoline gallon equivalent)
  - Per units of resource (e.g., per ton of biomass)

GREET data sources and ANL interactions with others

- **GREET overarching goal**
  - Build a consistent LCA platform with reliable, widely accepted methods/protocols
  - Maintain openness and transparency of LCAs by making GREET publicly available
- **Data are key to GREET reliability**
  - Open literature and results from other researchers
  - Baseline technologies and energy systems: EIA AEO projections, EPA eGrid for electric systems, etc.
  - Consideration of effects of regulations already adopted by agencies
  - Fuel production processes (WTP)
    - ANL simulations with chemical processing models such as ASPEN Plus
    - Interactions with energy companies via US DRIVE
    - Interactions with new fuel producers
  - Vehicle operations (PTW)
    - ANL Autonomie team modeling results for DOE VTO/FCTO and US DRIVE
    - OEM research results and interactions via US DRIVE
    - EPA MOVES and other models

TECHNOLOGY BUSINESS CASE EVALUATION

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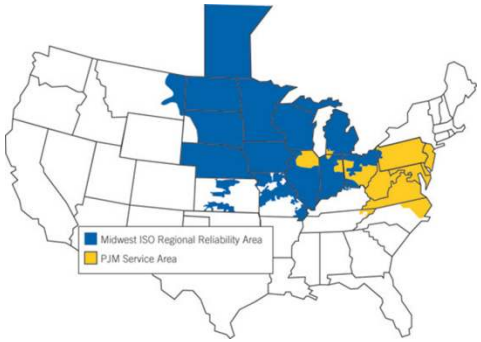
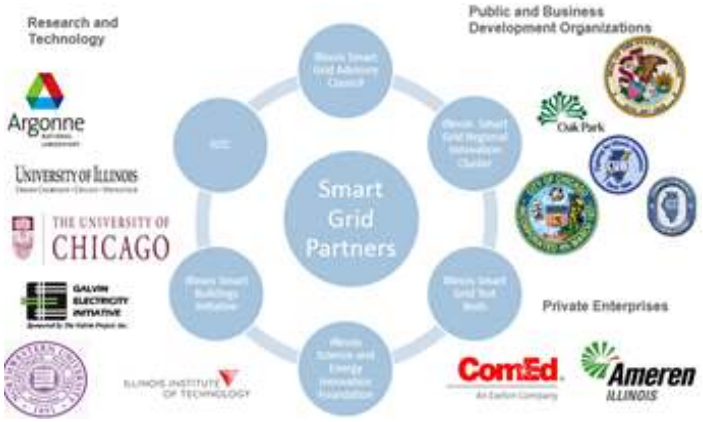
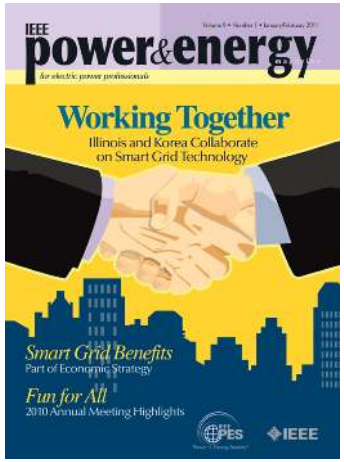
TECHNOLOGY BUSINESS CASE EVALUATION AND ENABLING POLICY





Technology Evaluation, Enabling Policy and Sustainable Business models

Pilot Testing and Commercialization of Innovative Technology



Survey of Industry Best Practices

THANK YOU.

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