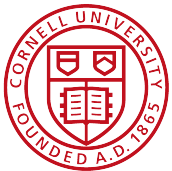


# Renewables Integration: *Challenges & Research Directions*



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# Outline

- Motivation
- Challenges
- Renewables integration today
- The opportunities tomorrow

# The Push for Renewables

Current % penetration in US is modest...

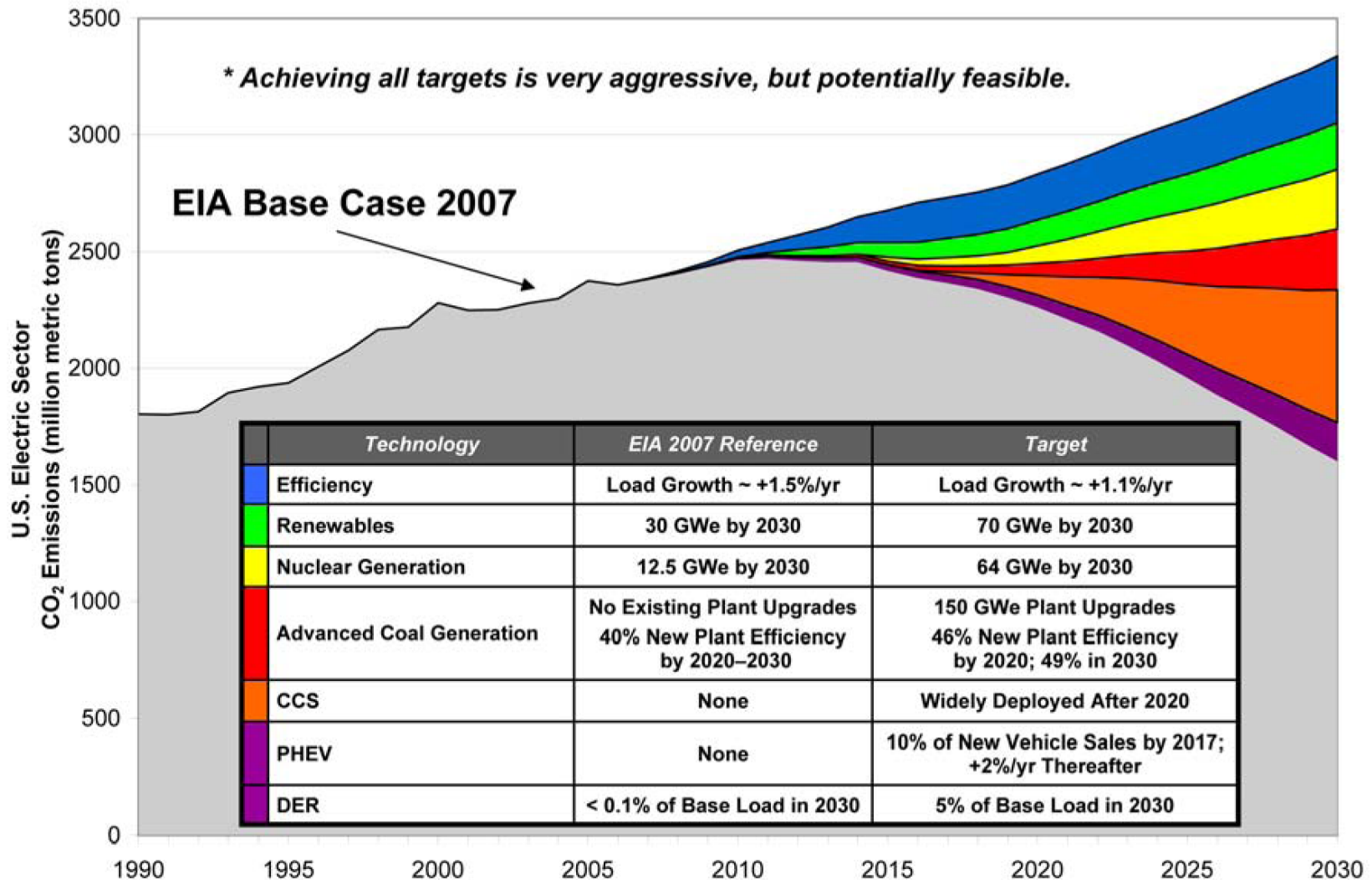


...but there is a lot coming and it's coming fast.

# Drivers for Change

- Global climate change
  - Reduction of carbon emissions
- Energy security
  - Geopolitically stable production of fossil fuels
- Economic growth in the developing world
  - Production and distribution of energy in usable forms
  - Electricity and transportation

# EPRI Prism Chart



# Challenges

- Large levelized costs – expensive relative to natural gas
- Limited transmission access – requires construction of new lines
- Variability – requires “backup” generation

Type	CF(%)	Cap	Fixed O&M	Var O&M	Trans	Total
Gas	87	17.9	1.9	42.1	1.2	63.1
Coal	85	65.3	3.9	24.3	1.2	94.8
Wind	34	83.9	9.6	0.0	3.5	97.0
CCS	85	92.7	9.2	33.1	1.2	136.2
PV	25	194.6	12.1	0.0	4.0	210.7
Offshr	34	209.3	28.1	0.0	5.9	243.2

- Numbers don't account for variability costs
- Not competitive with gas

Source: EIA, Estimated levelized cost  
(\$/MWh) of new generation resources, 2016

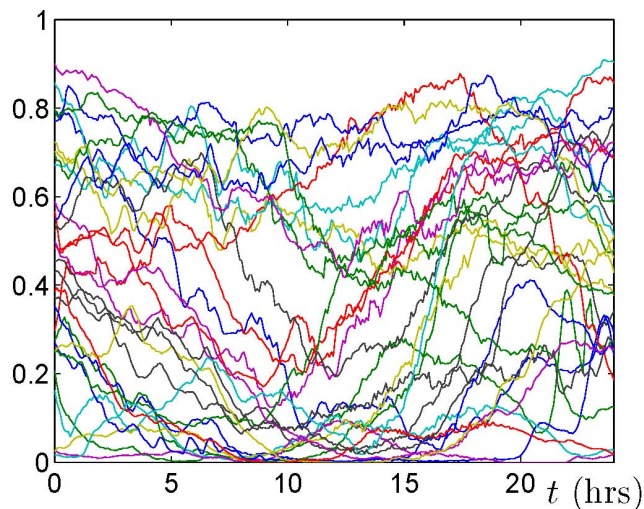
# The Variability Challenge

Wind and solar are **variable** sources of energy:

- **Non-dispatchable** - cannot be controlled on demand
- **Intermittent** - exhibit large fluctuations
- **Uncertain** - difficult to forecast

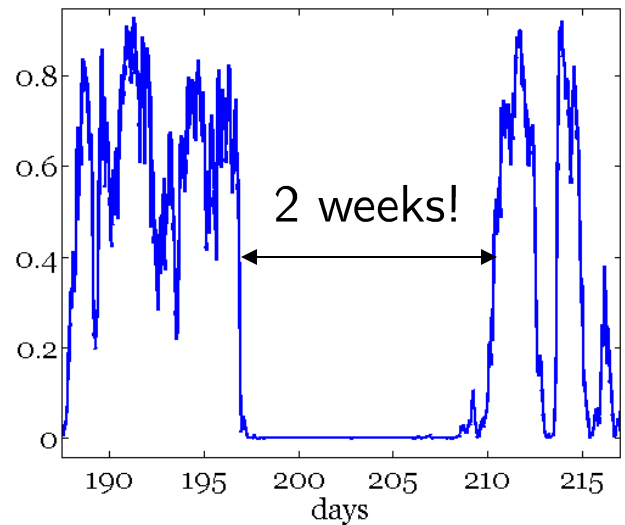
*Wind is a non-stationary process!*

Huge variance in daily patterns



*EX: Aggregate  
wind power  
across BPA*

Non-stationary process





# Wind Integration Today

Aggressive **RPS targets** in many states (e.g. CA 33% by 2020)

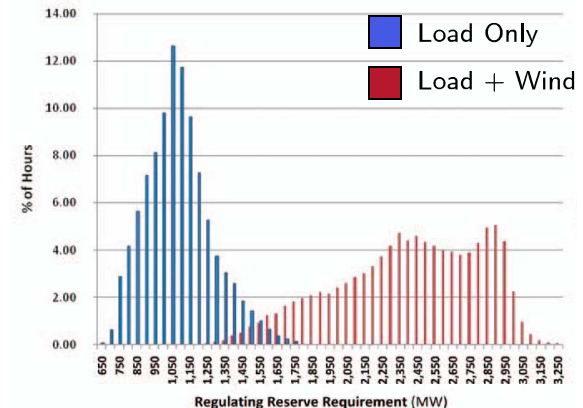
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## Commonly used subsidies

- **Guaranteed grid access** - all wind taken, treated as negative load
  - **Feed-in tariff (FIT)** - fixed per-unit price for energy produced
  - **Production tax credit (PTC)** - 2.2 cent per kilowatt-hour tax credit
  - **Variability cost exemption** - cost of reserves socialized among LSE's
- 

The current approach **will not scale – early signs....**

- Increased **reserve requirements**
- Subjection of wind to **reserve costs**
- Federal **PTC may expire**
- Competition from **natural gas**



Source: NREL, "EWITS," Final Report, 2010.

# Competition from Natural Gas

We are experiencing a **boom in natural gas** production

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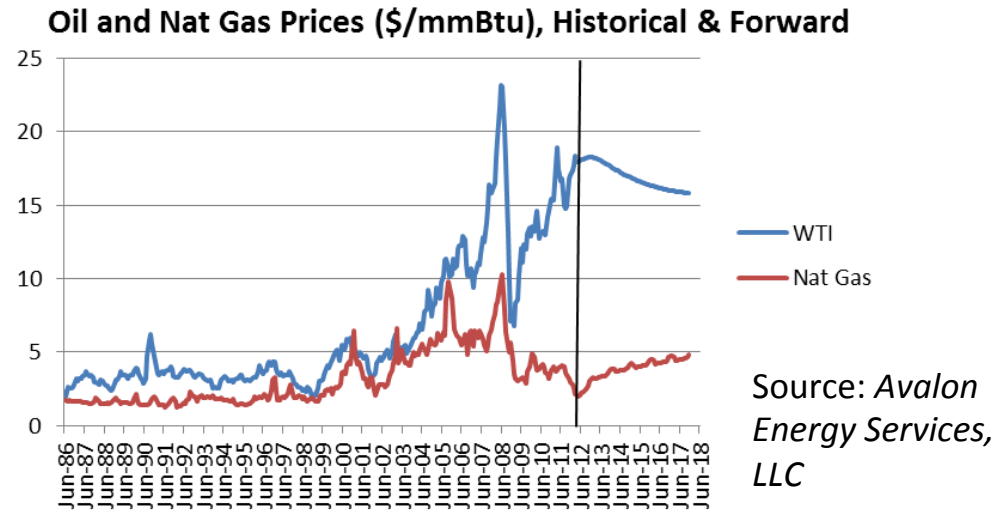
## Perceived benefits

- **Sharp decline in cost**
  - **Cleaner** than trad. fossil fuels
  - **Dispatchable**
- 

## Potential pitfalls

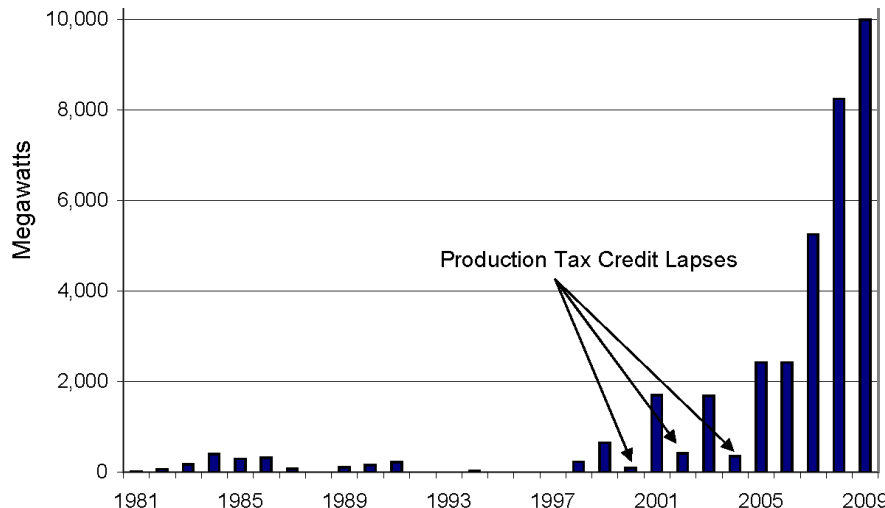
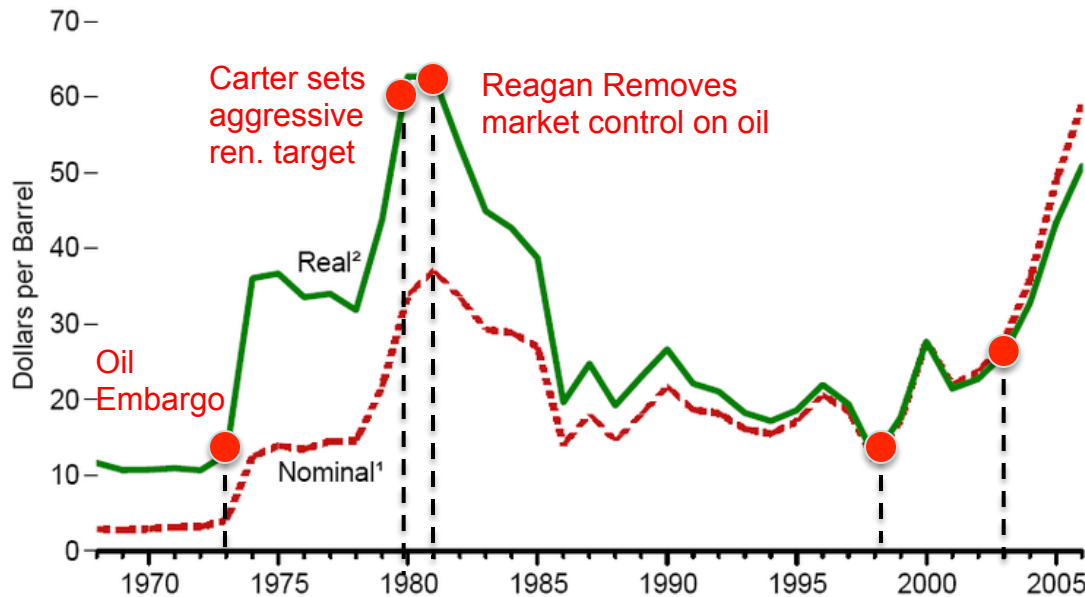
- **Price will not remain low** due to arbitrage with oil, environmental costs
  - **Hidden emissions** due to flaring and fugitive losses mitigate GHG savings
- 

- Shortsighted to abandon renewables in favor of gas
- Gas can **complement wind!**



# Are we Doomed to Repeat the Past?

Imported Costs



Source: EPI from GWEC, Worldwatch, AWEA

**1973.** OAPEC oil embargo

**1980.** Carter administration sets goal of 28% renewable energy penetration.

**1981.** Renewables lose their competitive edge after the collapse of world oil prices in the early 1980's and the expiration of Federal tax credits.

**2003-04.** Increased fuel costs and concerns of global warming led to renewed interest in renewables

**Today.** Will natural gas kill renewables?

# Making Renewables Competitive

## **Supply side Solutions**

- Penalties for injected variability → optimal contracts
- Firming with local generation, storage, better forecasting
- Aggregation strategies

## **System Operations Solutions**

- Stochastic optimal dispatch coupling decisions across time
- Improved forecasting on multiple horizons

## **Demand side Solutions**

- Resource management architecture: GRiP
- Coordinated control of end-use devices
- Market mechanisms to induce consumer participation

# Course Outline

<b>0900 - 930am</b>	<b>Introduction: Renewable integration issues</b>
<b>0930 - 1045pm</b>	<b>Supply Side Solutions</b>
	Optimal Contracts
	Aggregation
<b>1100 - 1200am</b>	<b>System Operations Solutions</b>
	Risk Limiting Dispatch
<b>1330 - 1500pm</b>	<b>Demand Side solutions</b>
	Architectures, Distributed resource coordination
	Demand Response: control and pricing
<b>1515 - 1530pm</b>	<b>Conclusions and other opportunities</b>