Long term national energy planning

Municipal Utilities 2030
Strategies for planning and sustainability
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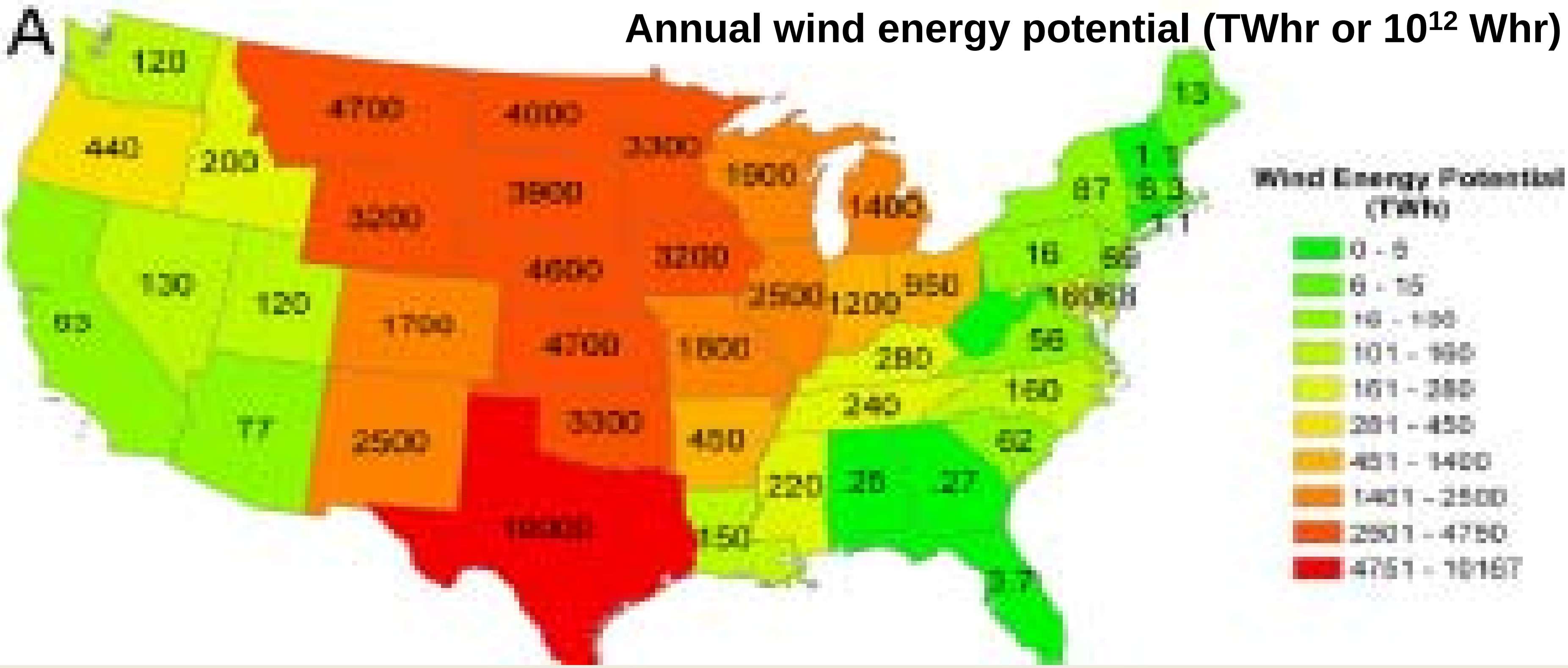
Outline

1. Winds of change
2. The US Energy System
3. Possible Futures for the US
4. Needs for new planning tools

Winds of change:
US Wind Resources

Annual wind energy potential (TWhr or 10^{12} Whr)



Total onshore energy potential is 62PWhr which is 2.1 × Total annual US energy consumption of 100 Quads

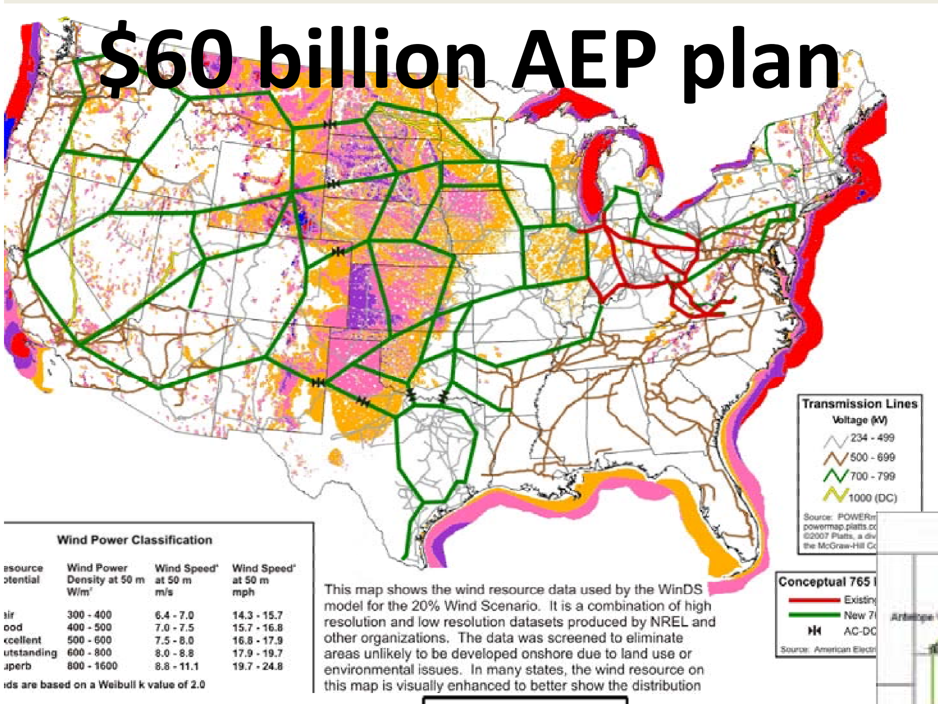
20x20 DOE Report: "The nation has more than 8,000 GW of available land-based wind resources that industry estimates can be captured economically ." (~24.5 PWhrs)

Analysis assumes (a) sites having capacity factor > 20% included; (a) loss of 20% and 10% of potential power for onshore and offshore, respectively, caused by interturbine interference, (c) offshore siting distance within 50 nm (92.6 km) of nearest shoreline.

Source: Xi Lua, M. McElroya, and J. Kiviluomac, "Global potential for wind-generated electricity," Proc. of the National Academy of Sciences, 2009, www.pnas.orgcgidoi10.1073pnas.0904101106.

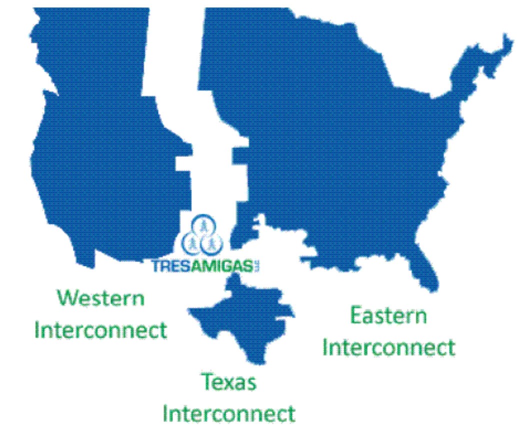
Winds of change
Building Transmission Superhighways

$60 billion AEP plan

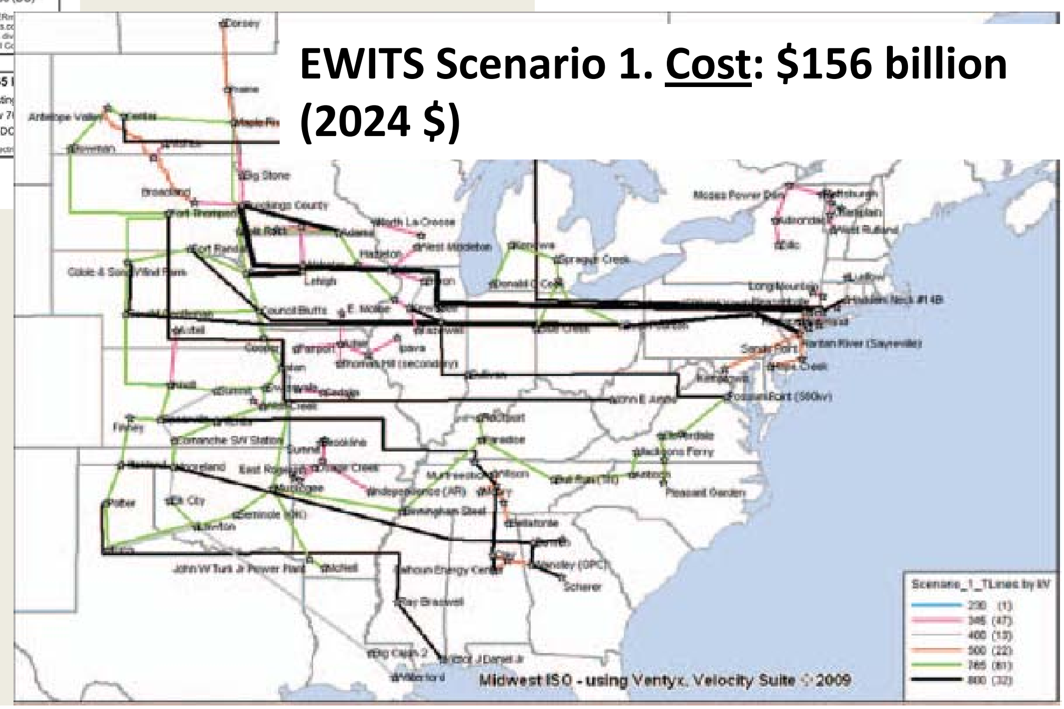


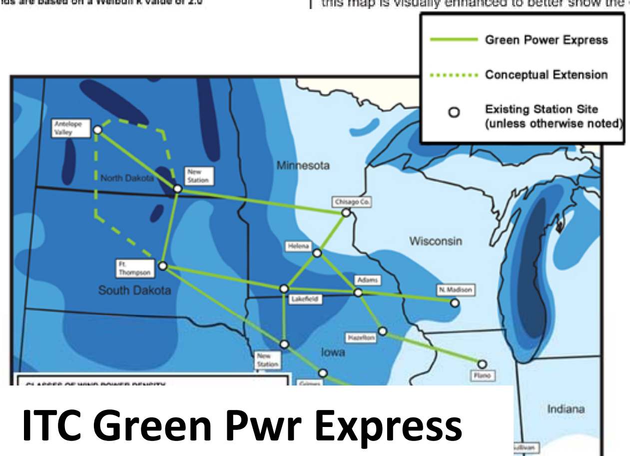
SPP conceptual plan

Tres Amigas Superstation



EWITS Scenario 1. Cost: $156 billion (2024 $)





ITC Green Pwr Express
Cost: $10 billion

Energy System: Transport goes electric!

In 2008, Warren Buffet's MidAmerican Energy Holdings bought 9.9% of BYD for $232 million.

And in 2009 Warren bought BNSF!

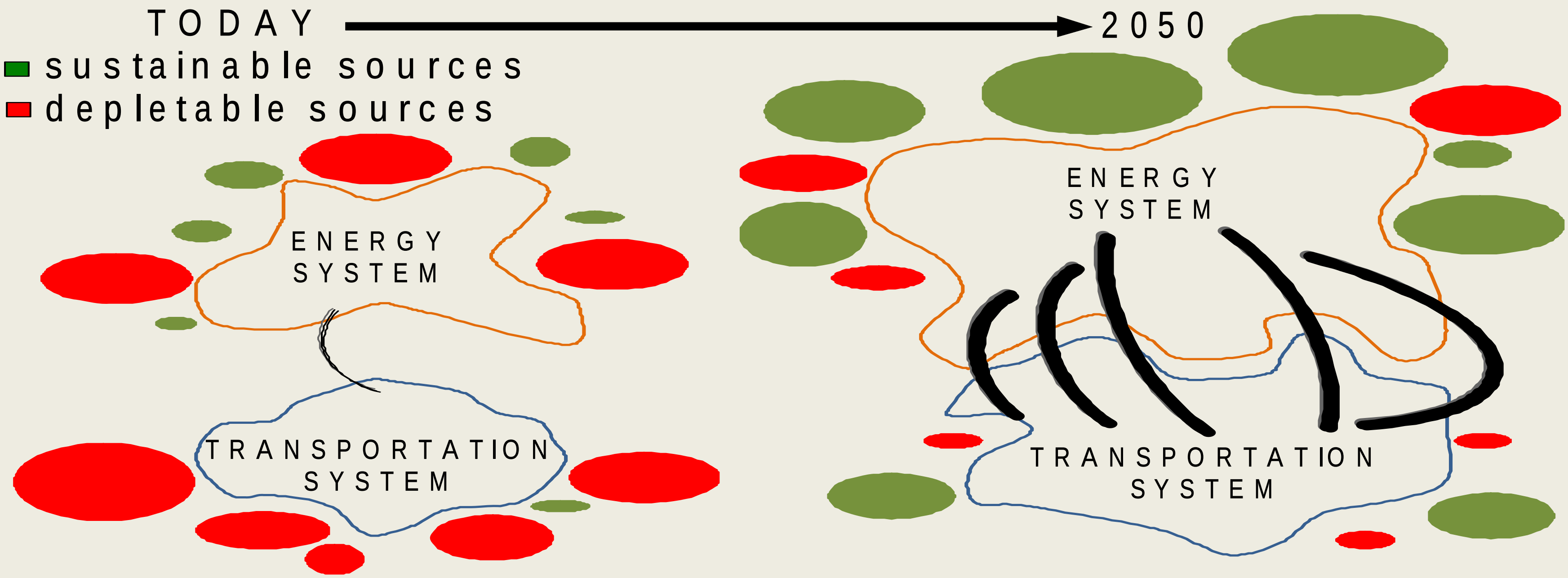
A modified French high-speed train has set a new world speed record for a train on conventional rails of 357 mph.

World's first all-electric locomotive has over 1,000 batteries, runs 24 hours on a single charge.

Rail ROW

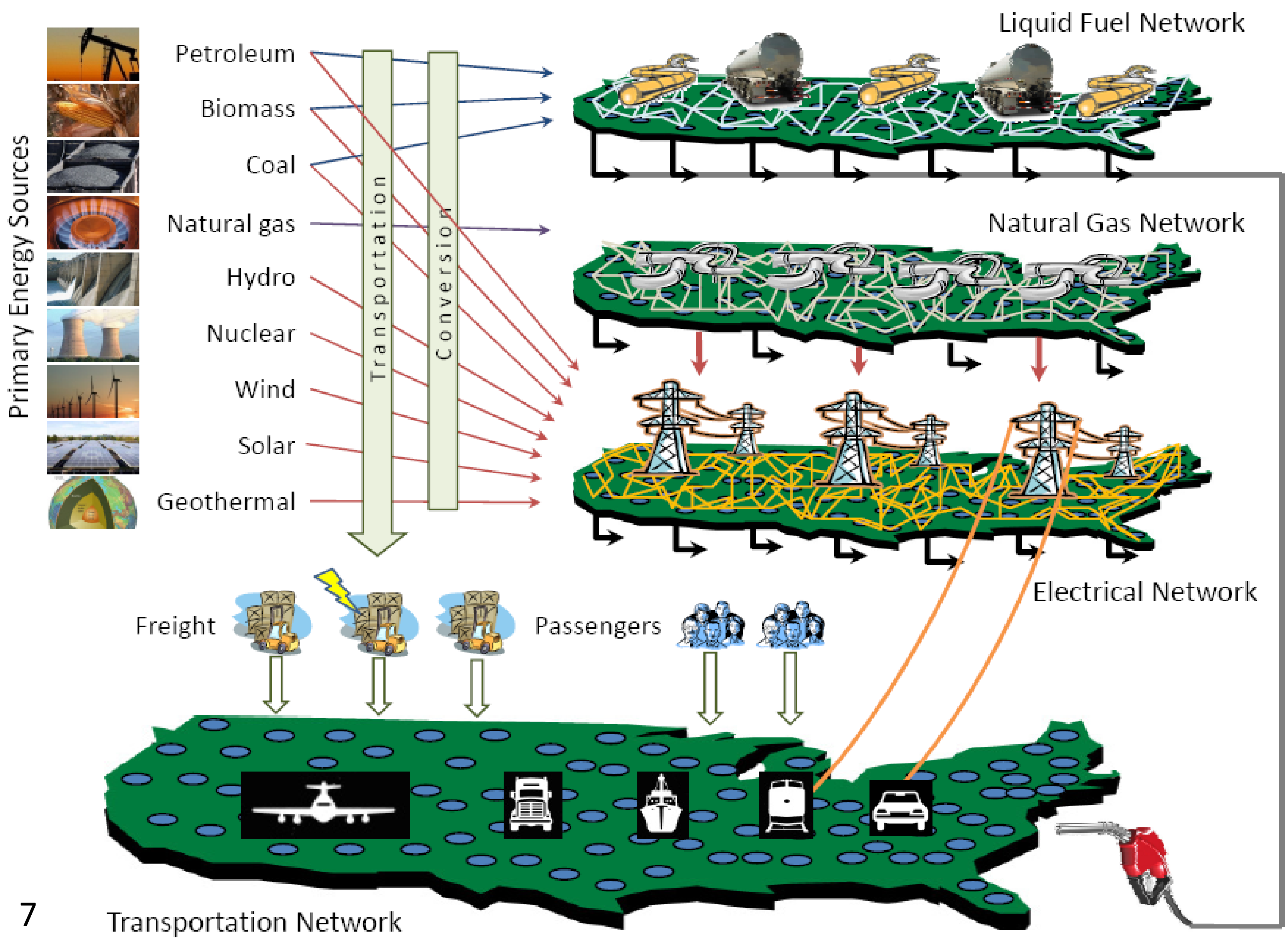
- Cost of an 800 kV HVDC line about $3M per mile
- Cost of converter stations land-multiple acres-negotiated
- ROW share from 15% in Missouri to about 50% on the east coast
- Annual fixed return on investment 12-13%.
- $260M/yr for two 1200 mile ROW minimum. Could have 7 lines or more.

40-year national modeling process

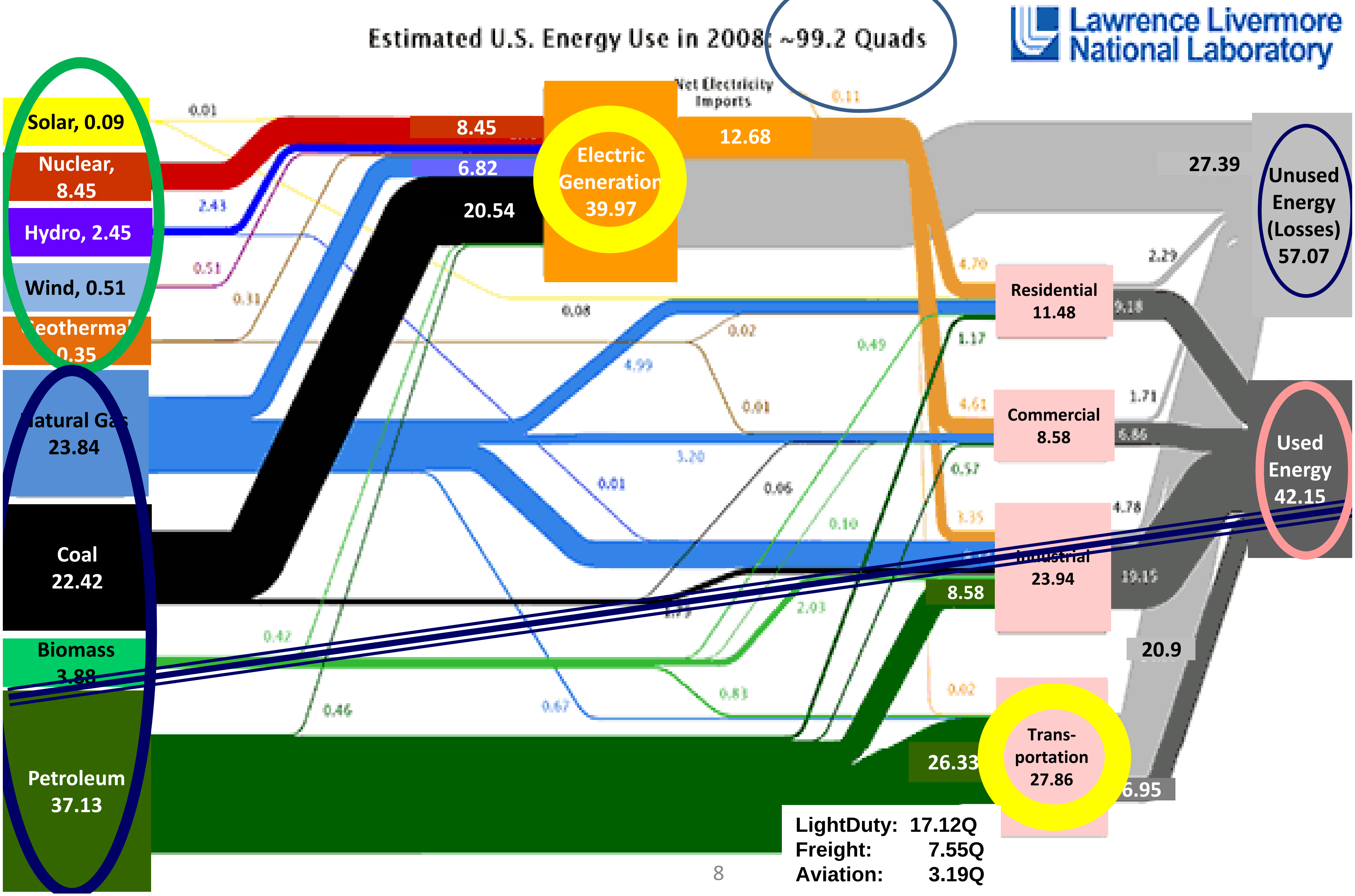


- Do we have a way to probe the future?
- Is our dialogue and legislation informed?

US Energy system: Electric, Fuels, Transportation



US Energy system: Today (Sankey diagram)



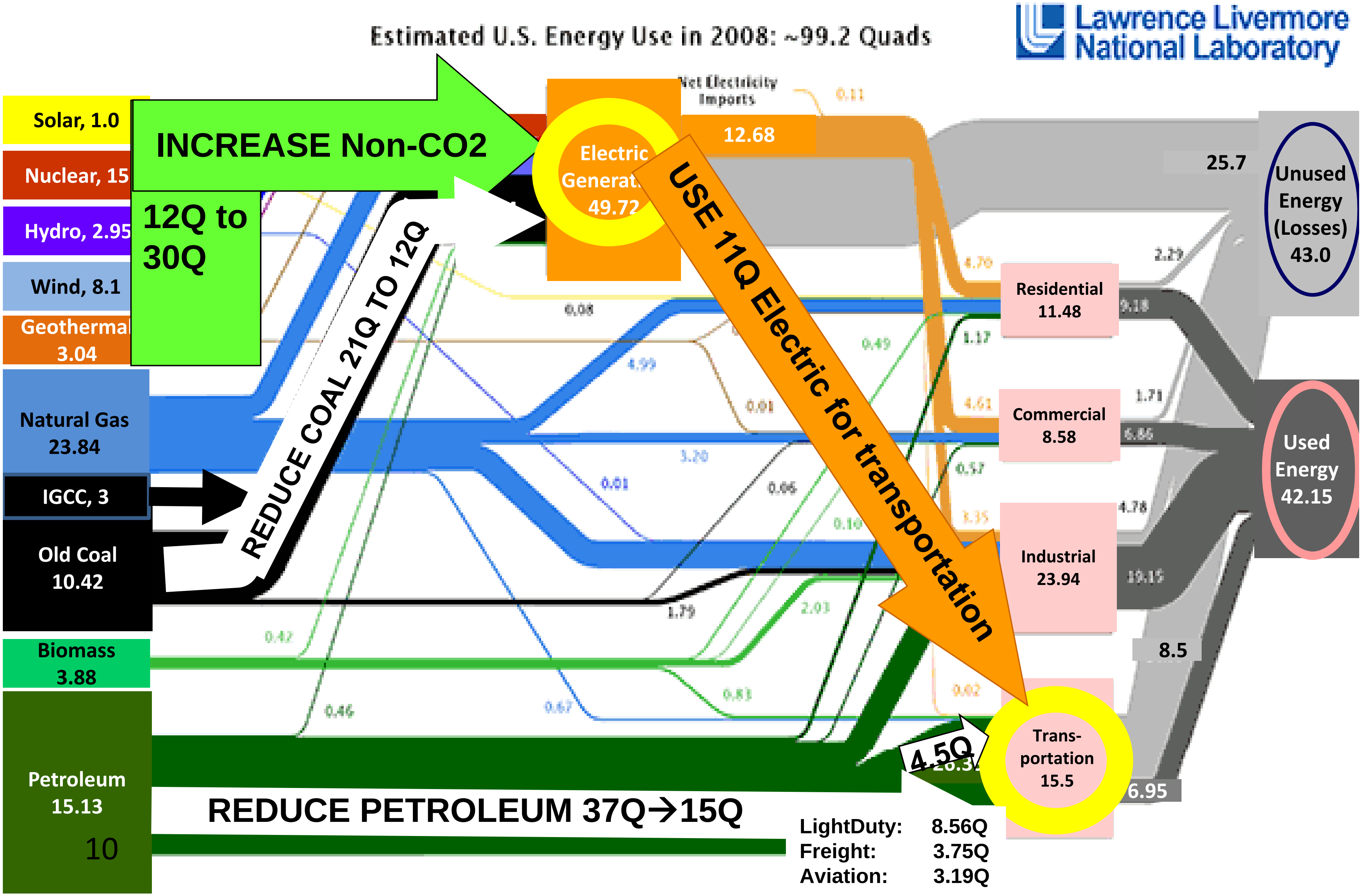
Energy system: Today

US ENERGY USE IS 68% ELECTRIC & TRANSPORTATION

GREENING ELECTRIC & TRANSPORTATION ENERGY SOLVES THE EMISSIONS PROBLEM

US CO_2 EMISSIONS IS 74% ELECTRIC & TRANSPORTATION

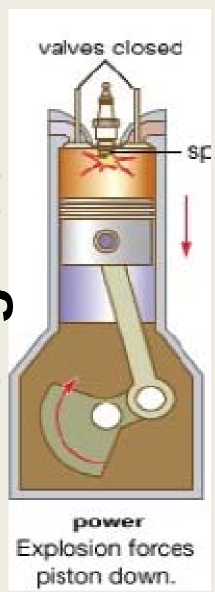
A possible future



A possible future: Why do we reduce losses?

Coal-fired power plants

Internal combustion engines



Because we reduced the use of combustion!

A possible future: emissions

•Decrease coal 21Q→12Q
•Decrease petroleum 37Q→15Q
•Increase Non-CO2 by 12Q→30Q (Wind 30GW→700GW)
•Use 11Q to electrify transportation

➔TOTAL CO_2 REDUCTION=2717 MMT CO_2

➔A 37.3% reduction over 2007 emissions.

➔Achieving this worldwide by 2035 results in a 75% chance of not exceeding the 2° guardrail.

Investment cost: $2.9trillion+cost of electrification

Annual savings in production cost: $264 billion

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Unit Costs

Technology	Overnight cost $/kW
Concentrated Solar	5021
PV Solar	6038
Nuclear	3318
Wind onshore	1923
Wind offshore	3851
Geothermal	4000*
Coal conventional	2058
Clean coal (IGCC+seq)	3500
Biomass	3766
NGCC	962

* Adjusted from EIA data, which gives cost of least expensive plant, which is $1711

Source: US DOE Energy Information Administration, "Cost and Performance Characteristics of New Central Station Electricity Generating Technologies," in "Assumptions to the Annual Energy Outlook," 2009, available at www.eia.doe.gov/oiaf/aeo/assumption/pdf/electricity.pdf

Other possible futures

North American Reliability Corporation, “2009 Long-Term Reliability Assessment: 2009-2018,” Oct 2009, at www.nerc.com/files/2009_LTRA.pdf

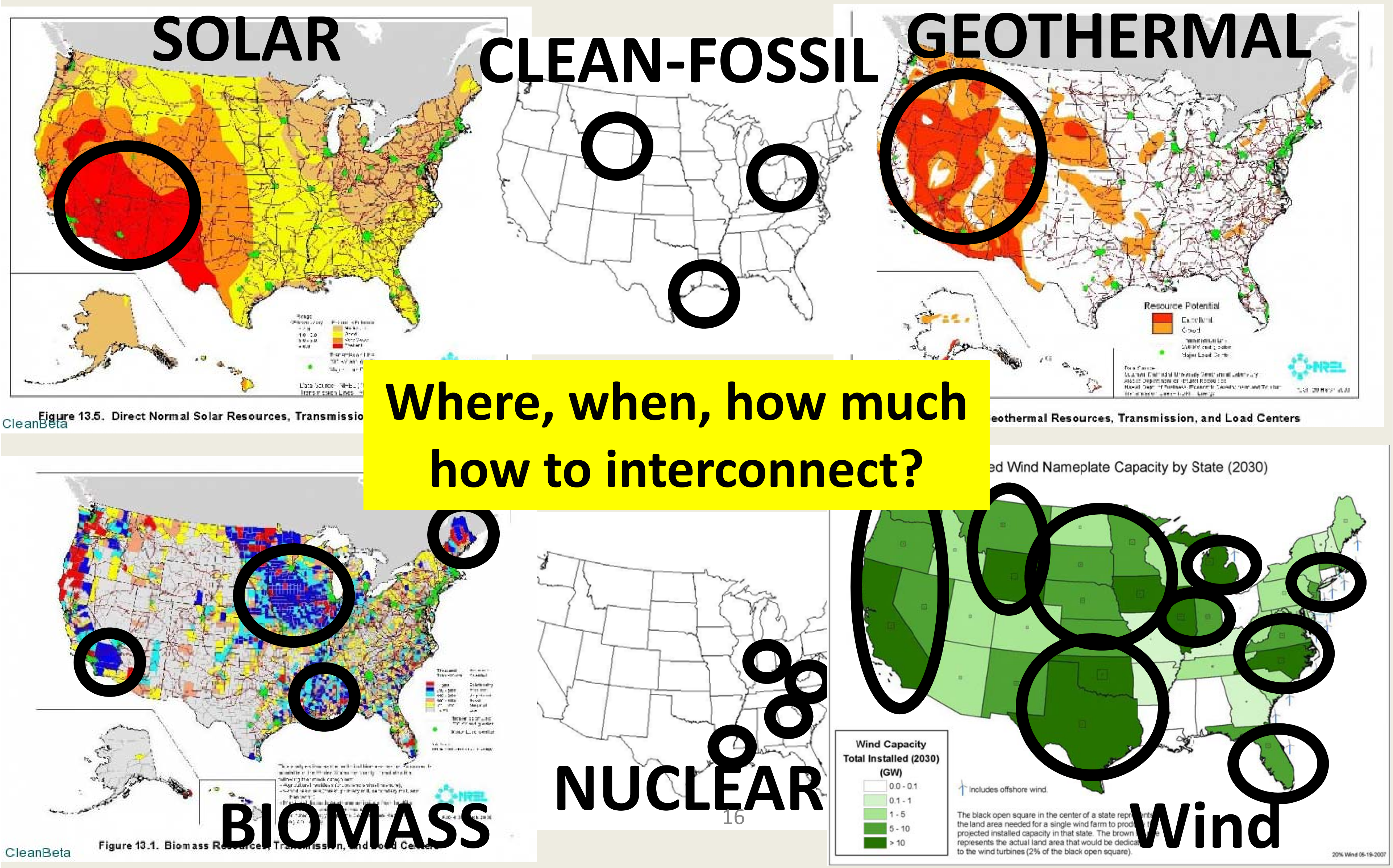
Union of Concerned Scientists, “Climate 2030, a Blueprint for a Clean Energy Economy,” May, 2009, at www.ucsusa.org/global_warming/solutions/big_picture_solutions/climate-2030-blueprint.html

National Academy of Engineering, “America's Energy Future: Technology and Transformation,” 2009, at http://nae.edu/nae/naepcms.nsf/weblinks/MKEZ-7UPQ5M?OpenDocument

Comparison of possible futures

Technolgy	Forecasted NERC, 2018		Hi Eff&Renewable UCS (NEMS), 2030		Hi IGCC/Seq, 16Q NAE, 2035		Hi Wind, 13.7Q ISU, 2035	
	ΔGW	Overnight cost Trillion $	ΔGW	Overnight cost Trillion $	ΔGW	Overnight cost Trillion $	ΔGW	Overnight cost Trillion $
Con Solar	20.4	0.102	238	1.195	-	0	65.5	0.329
PV solar	-	0	174	1.051	-	0	58.9	0.356
Nuclear	14.8	0.049	4.4	0.015	100	0.332	60.9	0.202
Wind onshore	229	0.440	670	1.288	350	0.673	630	1.211
Wind offshore	-	0	62	0.239	-	0	80	0.307
Geothrml	0.4	.002	31.8	0.127	-	0	106	0.424
Coal convntnl	19	0.039	red	0	red	0	red	0
IGCC+seq	-	0	7	0.024	400	1.400	29.5	0.103
NGCC	107	0.103	-	0	-	0	-	0
Biomass	-	0	157	0.591	-	0	-	0
TOTALS	389	0.735	1344	4.516	850	2.405	1031	2.930

Possible futures: more questions



Planning tools: what we need

1. Long-term (40 years) w/uncertainty representation

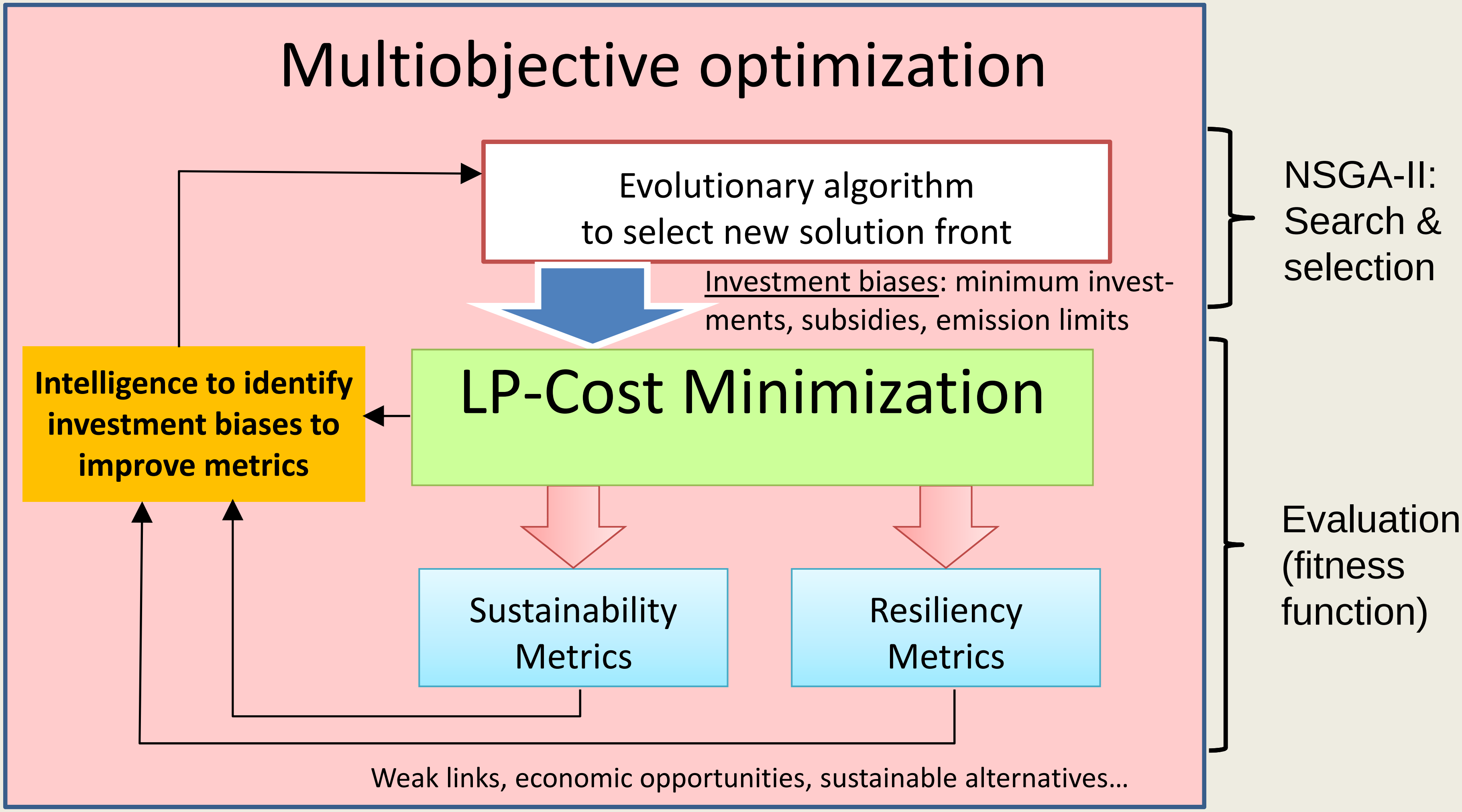
2. Multi-sector:
   Energy: fuels, conversion, transport, end-use
   Transportation: commodity & passenger

3. Policy-*driving*: optimization

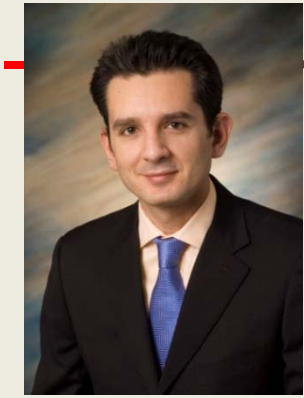
4. Multiobjective: cost, emissions, resiliency

5. Modeling granularity: identifies physical infrastructure

NETPLAN V1: Pareto front generation



NETSCORE21 Faculty & Students, Objectives


Dionysios Aliprantis, EE


Robert Brown, ME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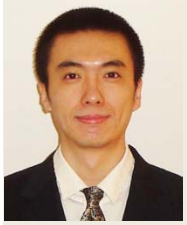
Jim McCalley, EE


Arun Somani, CpE


Lizhi Wang, IE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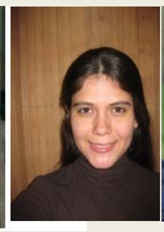
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PROJECT OBJECTIVES:

1. Identify & model de novo infrastructures
2. Develop assessment metrics for cost, resiliency, and sustainability
3. Formulate multi-commodity network flow/multi-objective program
4. Study interdependencies between energy and transportation systems
5. Provide 40-year national modeling process