Net-Zero Neighborhoods

…An Energy Plan A Scientist Will Love…

Gil Weigand
Oak Ridge National Laboratory

America is at Risk

- America is addicted to foreign oil
  - In 1970, we imported 24% of our oil. Today it is nearly 70% and still growing.
  - Largest wealth transfer ever known to the world is underway from the west to the middle east

- America is loosing jobs to foreign competitors
  - Since 1999 about 25% of America's manufacturing jobs have been lost to foreign competition*
  - Between 2001 and 2003 (that's 2 years), Goldman Sachs and Company estimates that 20% of U.S. technology jobs have moved overseas, including sophisticated design and innovation jobs

- America is not leading in the global energy and climate debate
  - Between 1990 and 2005 U.S. CO2e emissions rose by 1 billion tons (GT) to 7.2 GT/yr
  - Between 2005 and 2030, additional growth of CO2e emissions will be 2.5 GT** (35%)
  - U.S. faces growing energy needs and costs in all sectors: Residential, Commercial, Industrial, and Transportation
  - U.S. faces a progressive environmental policy discussion for the foreseeable future, including Cap and Trade, higher CAFÉ standards, renewables and conservation incentives, climate protocols, and NIMBY & BANANA***

These trends threaten our economy, our environment, our energy security, and our national security. They touch every part of our daily lives and tie our hands as a nation and a people.

* Apollo Alliance, www.apolloalliance.org
** U.S Department of Energy, Energy Information Agency
*** NIMBY: Not In My Back Yard; BANANA: Build Absolutely Nothing Anywhere Near Anything

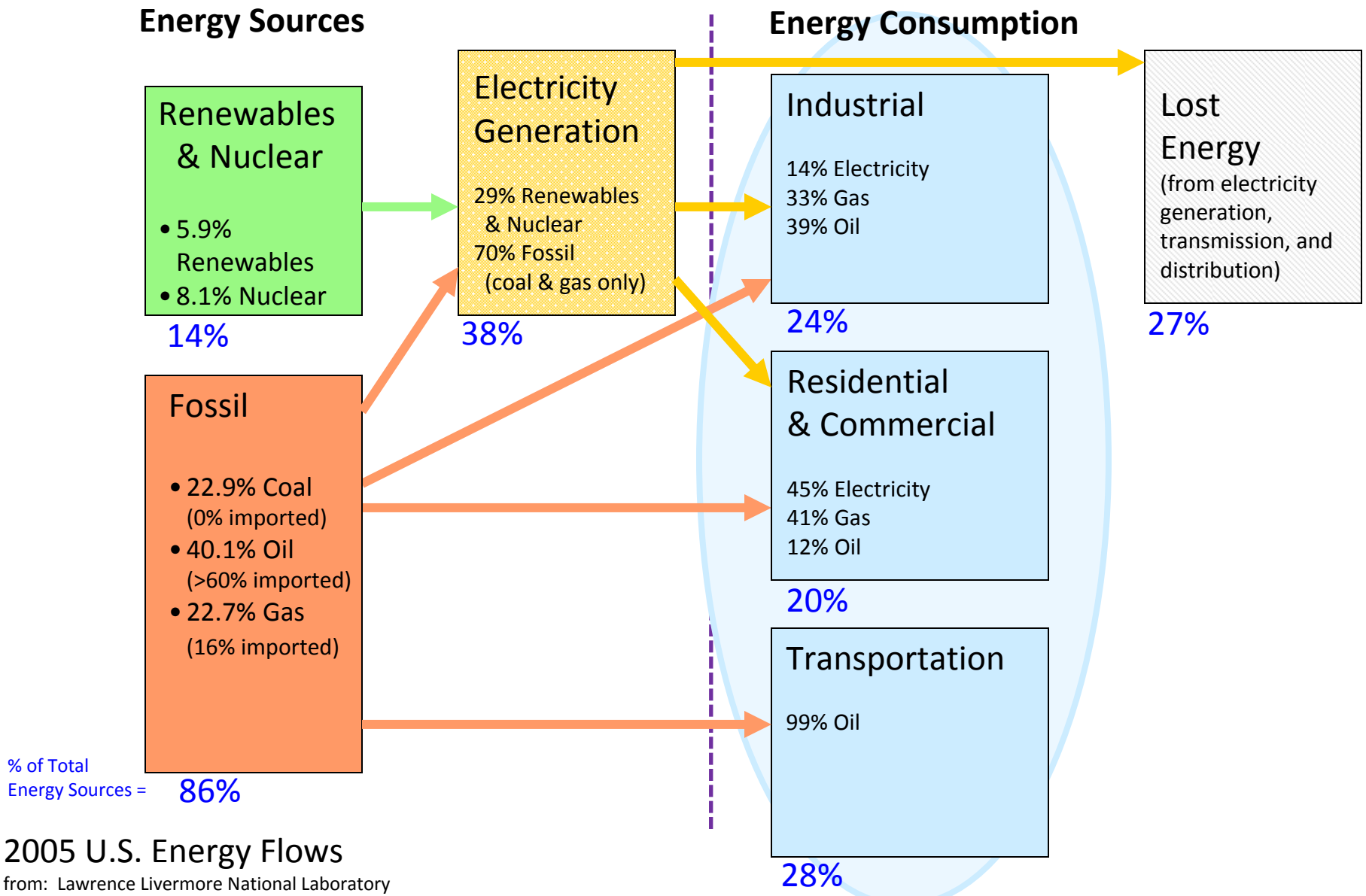
New World Order

U.S. (G-8) will get “hit” with a BRIC

Brazil, Russia, India, China

- Newly formed political and economic block
- Held first summit on 16 June 2009 in Russia
- Focus is economics including energy

U.S. Energy Consumption
--status quo no long viable--



2005 U.S. Energy Flows

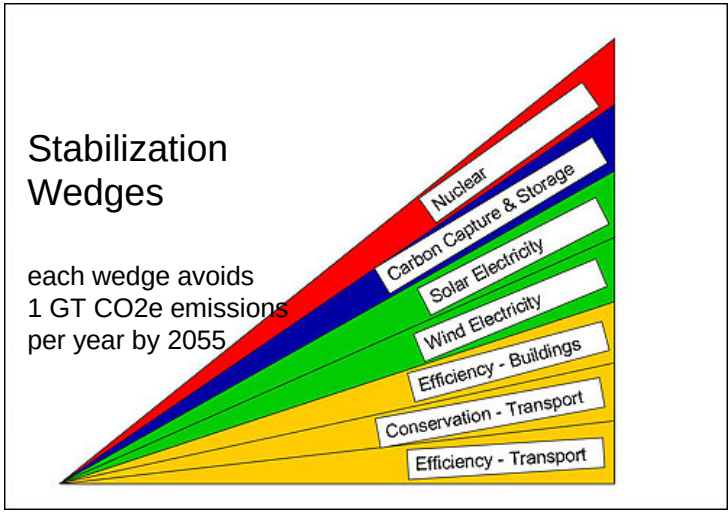
from: Lawrence Livermore National Laboratory

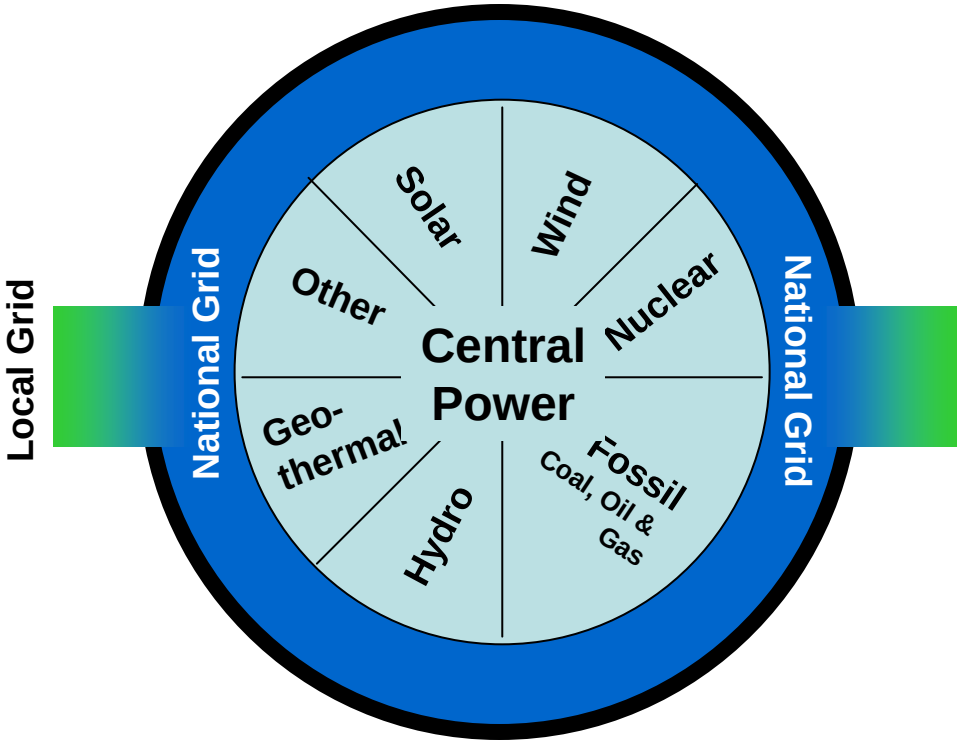
(Total U.S. energy sources = approximately 100 Quadrillion BTUs <=> 50 million railroad cars full of coal or 50 billion gas-tanks full of gasoline)

Conventional Wisdom Plans

--they will get us a long way towards our future goals but not all the way--

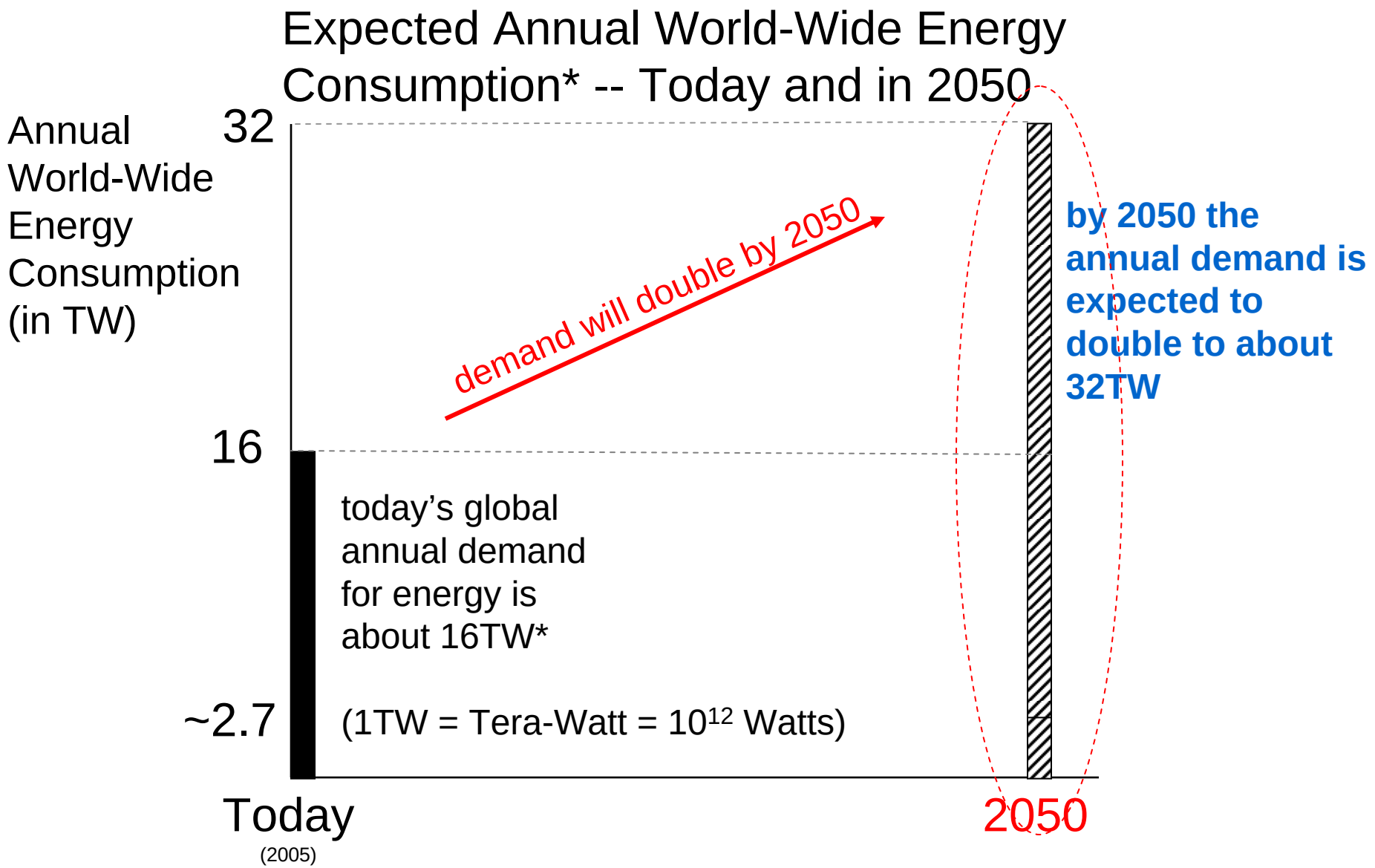
- Generally conventional wisdom involves some version of the "stabilization wedges strategy"
  - Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technology, S. Pacala and R. Socolow, Science, August 13, 2004





- They are great plans, rely on current technologies, and can be implemented immediately
- Conventional wisdom plans nevertheless are finding that there are real-world realities that are preventing or slowing progress on implementation objectives

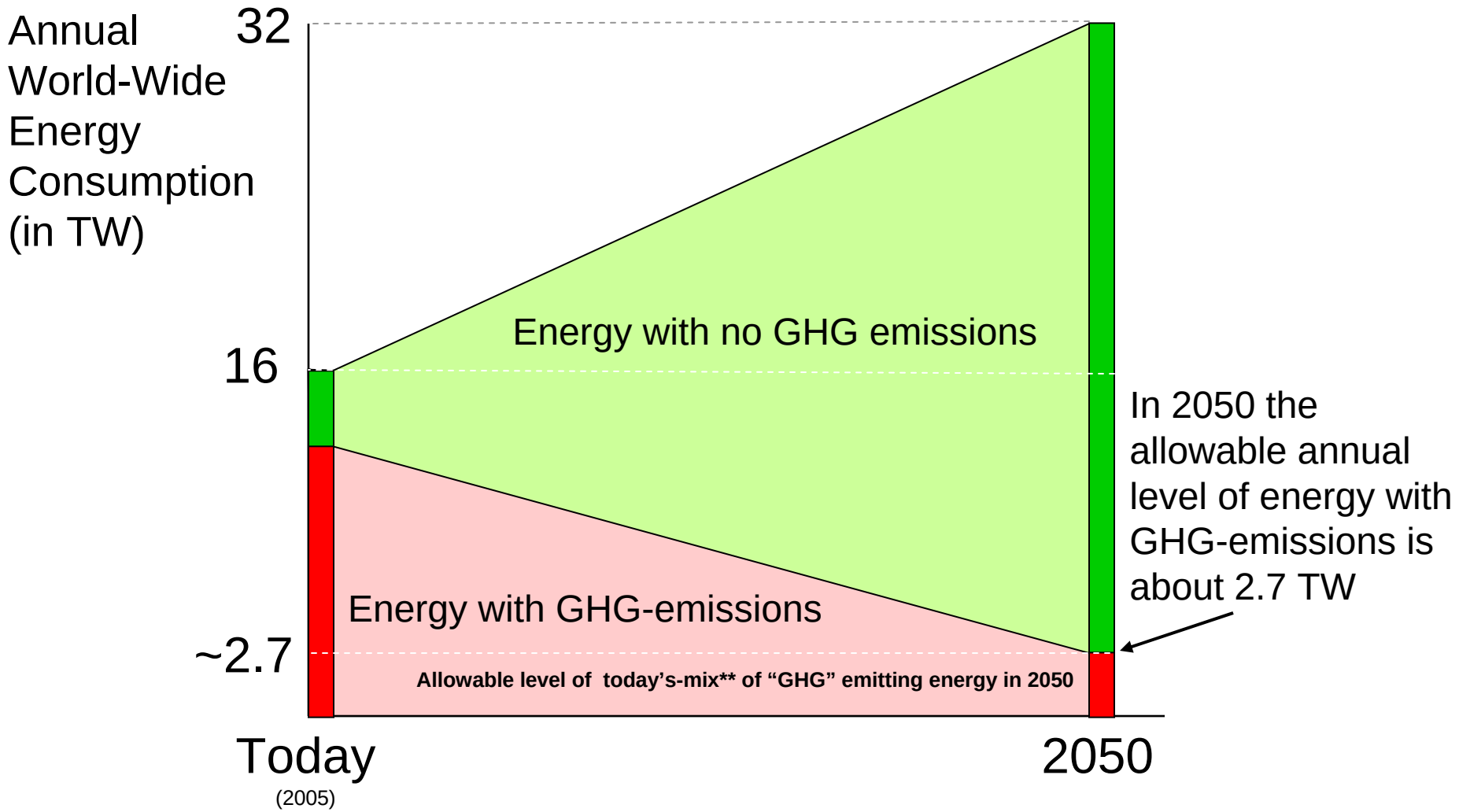
Meet "Mr." Reality



* U.S. Department of Energy, Energy Information Administration

USA consumption = ¼ of World-Wide

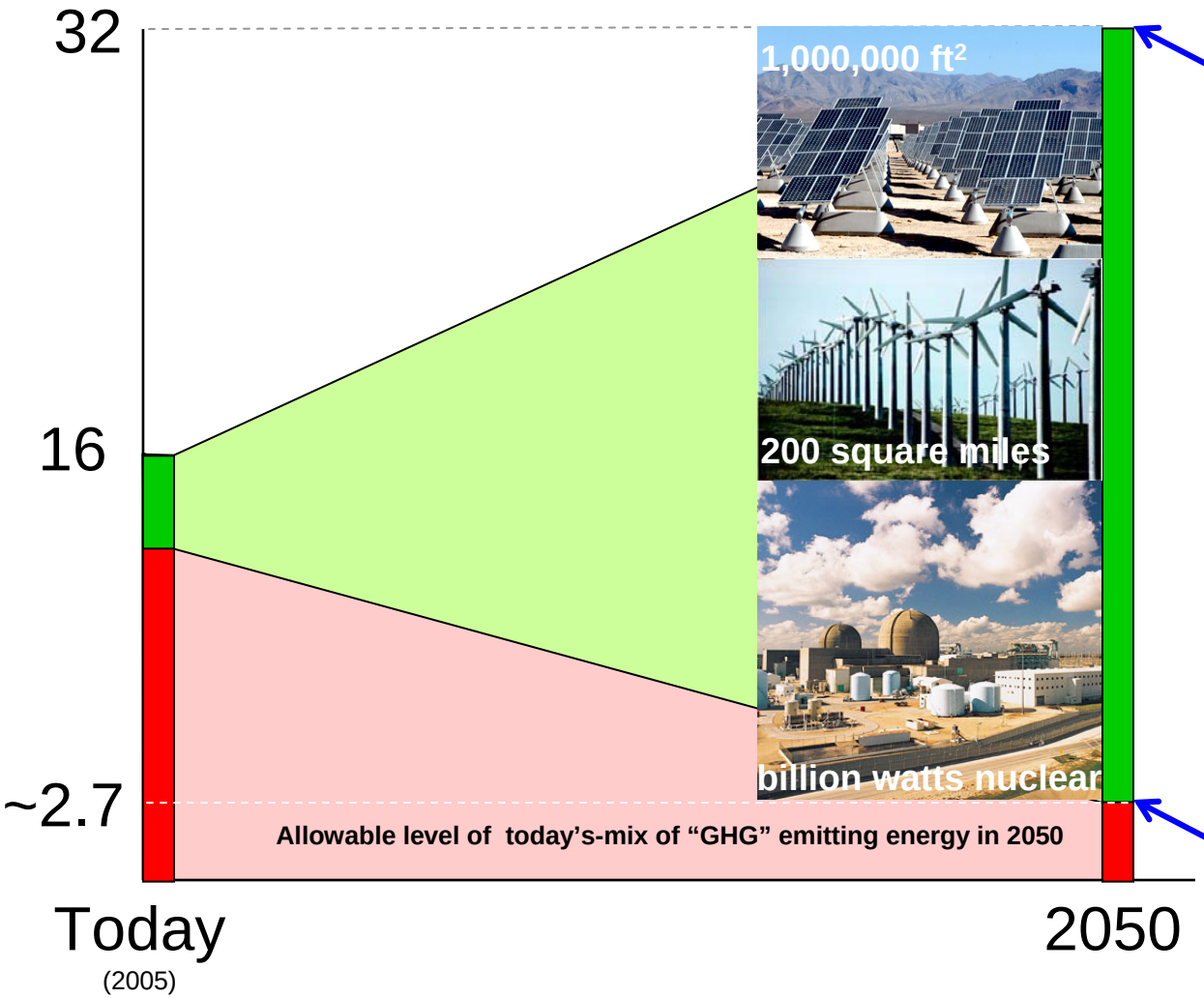
Achieving a World-wide Goal of an 80% Reduction from the 1990 levels of GHG emissions by 2050



* U.S. Department of Energy, Energy Information Administration ** today's mix (2005): 86.5% fossil, 7% renewables, 6.3% nuclear, U.S DOE, EIA

Meet "Mr." Reality

Achieving a World-wide Goal of an 80% Reduction from the 1990 levels of GHG emissions by 2050



every day, starting today and ending in 2050, add to the grid the equivalent of:

--one million square feet of solar panels,

--200 square miles of wind turbines, and

-- a one billion-watt nuclear power plant

U.S. consumption is ¼ of World-Wide

Energy Objectives Meet Reality of Environmental Concerns

Meet the Latest “Mr.” Reality

- Pickens cancels massive Wind Farm in Texas
  - No electric grid to get energy to market… building own was technically not feasible
  - About 700 gigantic wind turbines on over 200,000 acres

- Wilderness Society sues DOE in federal court to halt National Transmission Corridors

The DOE must support “not so conventional wisdom plans”, for example

Net-Zero Neighborhoods Plan,

where there could be high payoff as part of a prudent near-term mitigation strategy

- Net-Zero Neighborhoods Plan changes the “game” for implementation. Its focus is: local; on consumers; mass market generation and storage near consumption, expand supply of renewable energy rapidly, lower cost energy, AEV, and transportation and storage integrated

- Not so conventional wisdom plans such as the Net-Zero Neighborhoods Plan can be implemented starting today with today’s technology but to fully realize the Plan’s goals there needs to be several years of results driven, focused, well funded R&D along with an end-to-end proof of concept demonstration

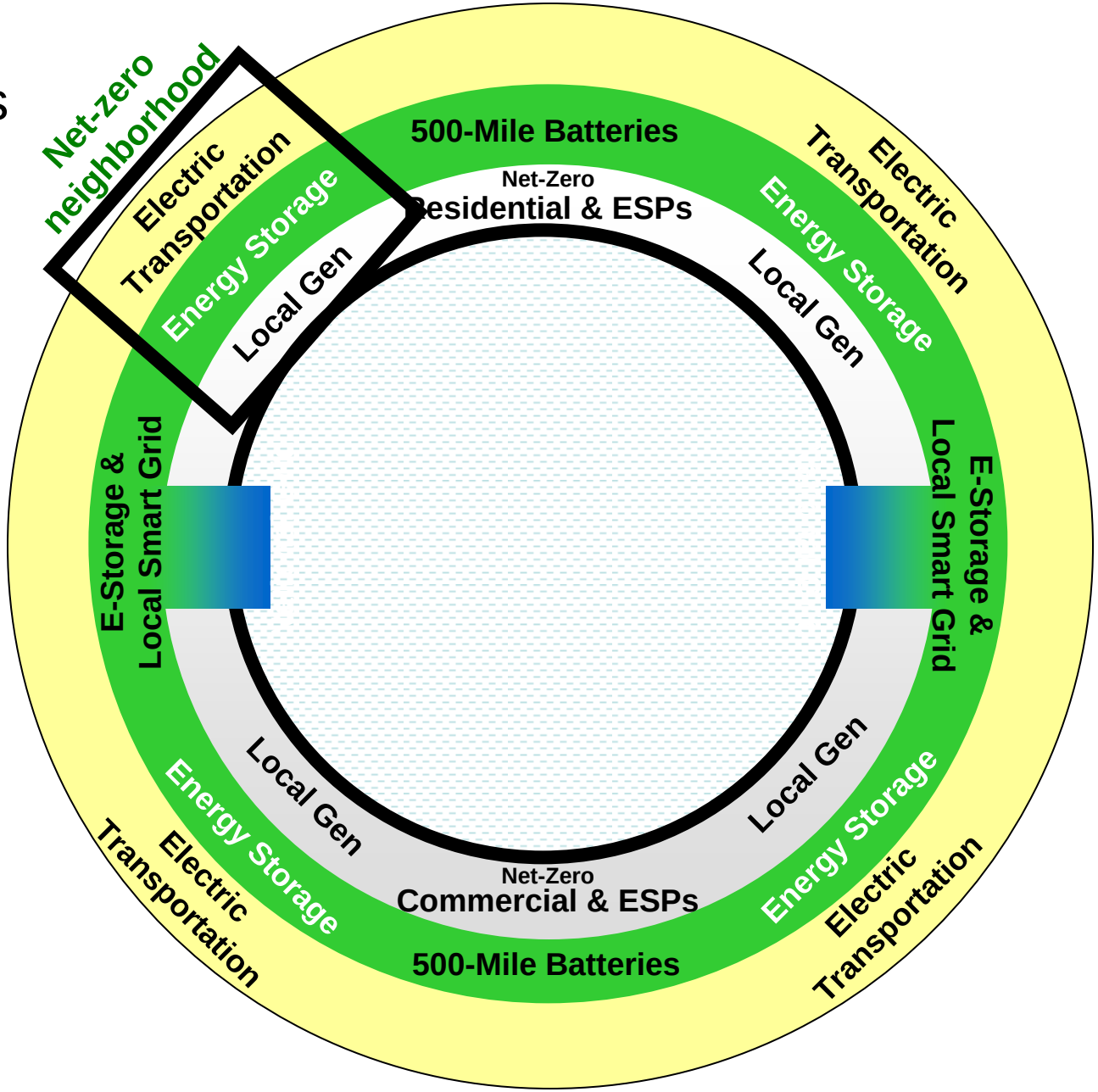
Net-Zero Neighborhoods --the English translation--

- Locate energy storage at point-of-sale in proportion to consumption (and population) +
- Generate energy locally using renewables +
- Electrify transportation +
- Unify energy storage and transportation +
- Commoditize energy, consumers buy and sell energy per their ability and needs in a localized open marketplace +
- Generates new jobs base in every locale in America; greater jobs base in green technology and manufacturing for America

  – No stress on current grid infrastructure
  – Consumer products for energy generation

Net-Zero Neighborhoods and the Smart Grid

- incorporate the energy storage (e.g., batteries) into the local smart grid
- electric transportation becomes point to point mass transit
- net-zero neighborhoods use local generation
- ESPs support net-zero neighborhoods along with providing local generation



Creating millions of new jobs building out net-zero neighborhoods in **every** district and community across America to generate up to 50% of the residential electricity from consumer systems

"turns land into gold"

- Generate energy locally with renewables, specifically consumer products—solar, wind turbines, biomass turbines, etc—supply the electricity
- Technology is viable in every community whether urban or rural
- ESP businesses' provide energy and conservation goods and services and JOBS, locally
- Homeowners and commercial building owners become energy suppliers; essentially they are entrepreneurial "mom and pop" utilities

Building a 21st century local smart grid

- Every energy type becomes base load regardless of temporal or geographical behavior
- Batteries become an integral part of the local smart grid infrastructure, both mobile and stationary systems
  - Storage for local consumer generation (net-zero neighborhoods)
  - Storage distributed in proportion to population and point of sale
  - Storage for intermittent sources or peak-use power demands, including the centralized, large-scale renewables
  - Point-to-point mass-transit transportation
    - Electric vehicles will ride on common/shared battery infrastructure
    - Zero-emissions commuting
  - Robust, survivable network
- Conservation and management in residential and commercial
- Neighborhood wide management of commerce in energy
  - Net-zero neighborhoods marketplace, including transportation, in energy
  - Utilities and other providers pre-position energy per their business plan
- Shifts emphasis in energy storage to broadly benefit public wellbeing

Net-Zero Neighborhoods Plan

At 50% market penetration The Net-Zero Neighborhoods Plan advances the President's agenda:

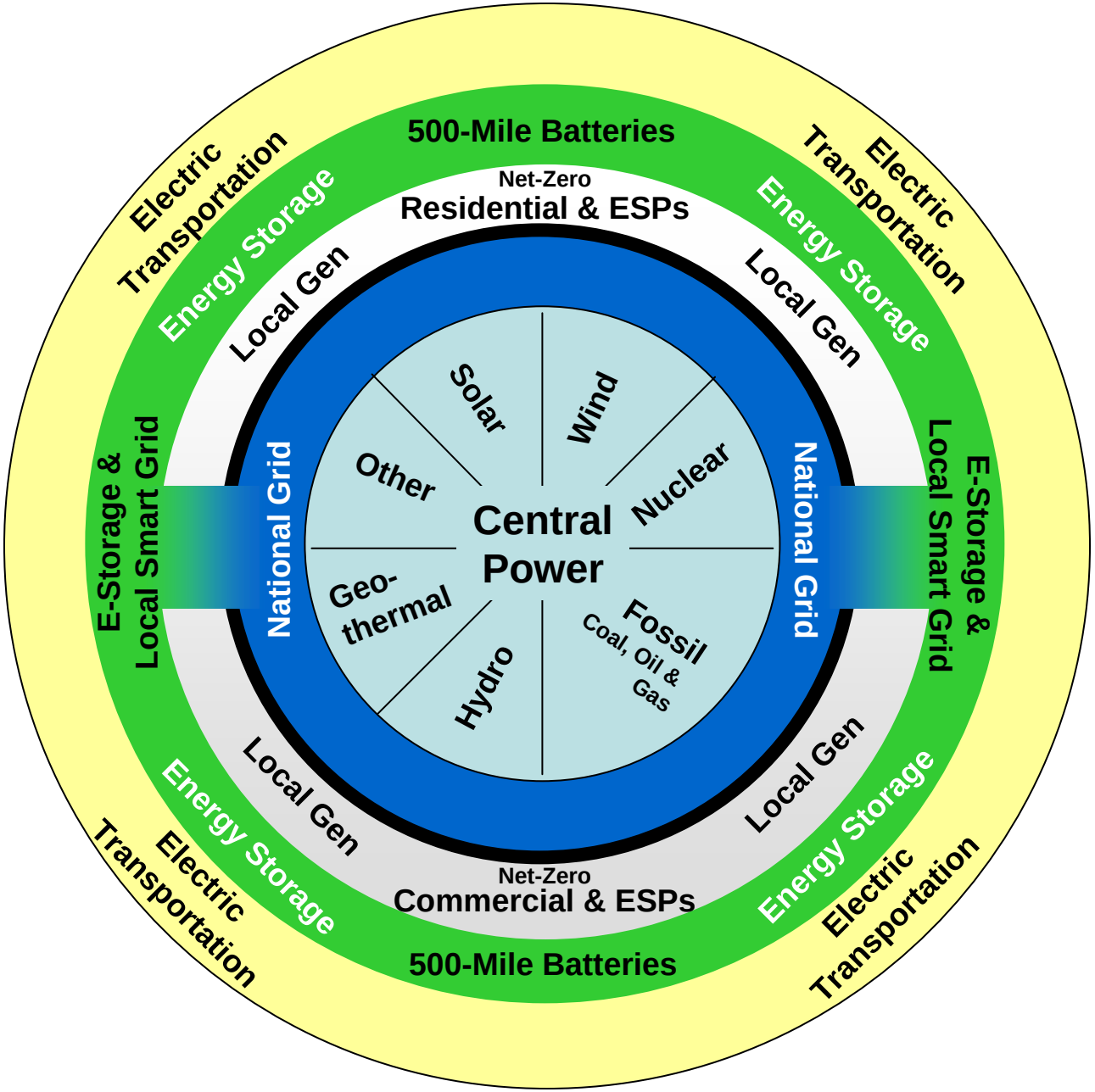
- Environmental Security Imperative—reduces total U.S. CO2 emissions by about 30%
- National Security and Energy Security Imperative—reduces oil imports by about 80%
- Economic Security Imperative—increases U.S. jobs that can not be outsourced

Technical Driver Actions Proposed for Net-Zero Neighborhoods Plan:

- mass market advanced interchangeable energy storage products (batteries) for both fixed residential and commercial and transportation
  - **needs "500 mile" battery** – initial effort focuses on Li-air thin film nano-technology
- the creation of grid-enabled consumer-side energy generation appliances
  - **needs 50% efficient photovoltaic cells** – 10x20 foot panel at consumer prices to be purchased at consumer home improvement stores; easy as a sprinkler system to install
  - consumer micro wind turbines and biomass generator systems
- create business services--**energy service providers-**--to provide consumer-side generation and efficiency services, incentives, and options
- **standards and protocols** which enable for the consumer an autonomous, ubiquitous energy economy
- widespread use of information products and services to drive efficiency and commerce for net-zero neighborhoods
- **The "iCar"–** can be considered a mobile energy (distributed) storage unit, an integral part of smart grid, that can be used for transportation. When plugged into the grid, energy can be withdrawn as required by the system per consumer controls and driving statistics. The iCar is transformational; it is based on marketplace driven requirements rather than an evolutionary car.

Net-Zero Neighborhoods and Conventional Wisdom

Is This the Best of All Around Approach and Winning National Strategy?



Towards a Carbon Free Energy in Residential/Household, Transportation, and Commercial Markets

NZN simulation

$$dE = f'_k(t, \ldots)dt$$

for all k

U NZN and NZN-ESP Renewables (local jobs!!)

Percentage NZN'Electric Transportation	50
Percentage NZN & NZN'ESP Generation	50

Base Load

Nuclear % of Total E

0 — 30 — U — 18

Coal e % of Total E

0 — 30 — U — 18

Coal x % of Total E

0 — 30 — U — 0

Other Base Load

PrePositioned Renewables
Units from Nat Grid

0.0 — 4.0 — U — 1.5

Small Nuclear % Total E

0 — 20 — U — 0

Hydro % Total E

0 — 10 — U — 3

Coal 50% Sequestratain % Total E

0.0 — 5.0 — U — 2.0

Percentage NZN-Electric Transportation -- % Market Penetration of Electric Vehicles in R&C Market;
e.g., 50 = 1/2 of all R&C vehicles are all-electric and 100 = all of R&C vehicles are all-electric
(zero emissions transportation)

Percentage NZN & NZN-ESP Generation -- % Market Penetration of NZN in R&C Market
(zero emissions local generation; mostly wind and solar)

MAKING ALL ENERGY FORMS A BASE LOAD CAPABILITY --- Energy Storage per R&C --- initial kWh per R&C of stored energy

Energy "Units" of Renewables PrePositioning;
one "Unit" = ~10 kWh per R&C per day

CO2e Emis…in Tonnes	4,532.1
CO2e Emis…sportation	7,906.0

Energy Storage

Generation Flows

Storage and Consumption

Total Stor…al in GWh\d	15.90
Total Energy in GWh\d	32.25
CO2e Tota…missions \d	12,438.1
Gallons of Gas \d	660,535.7

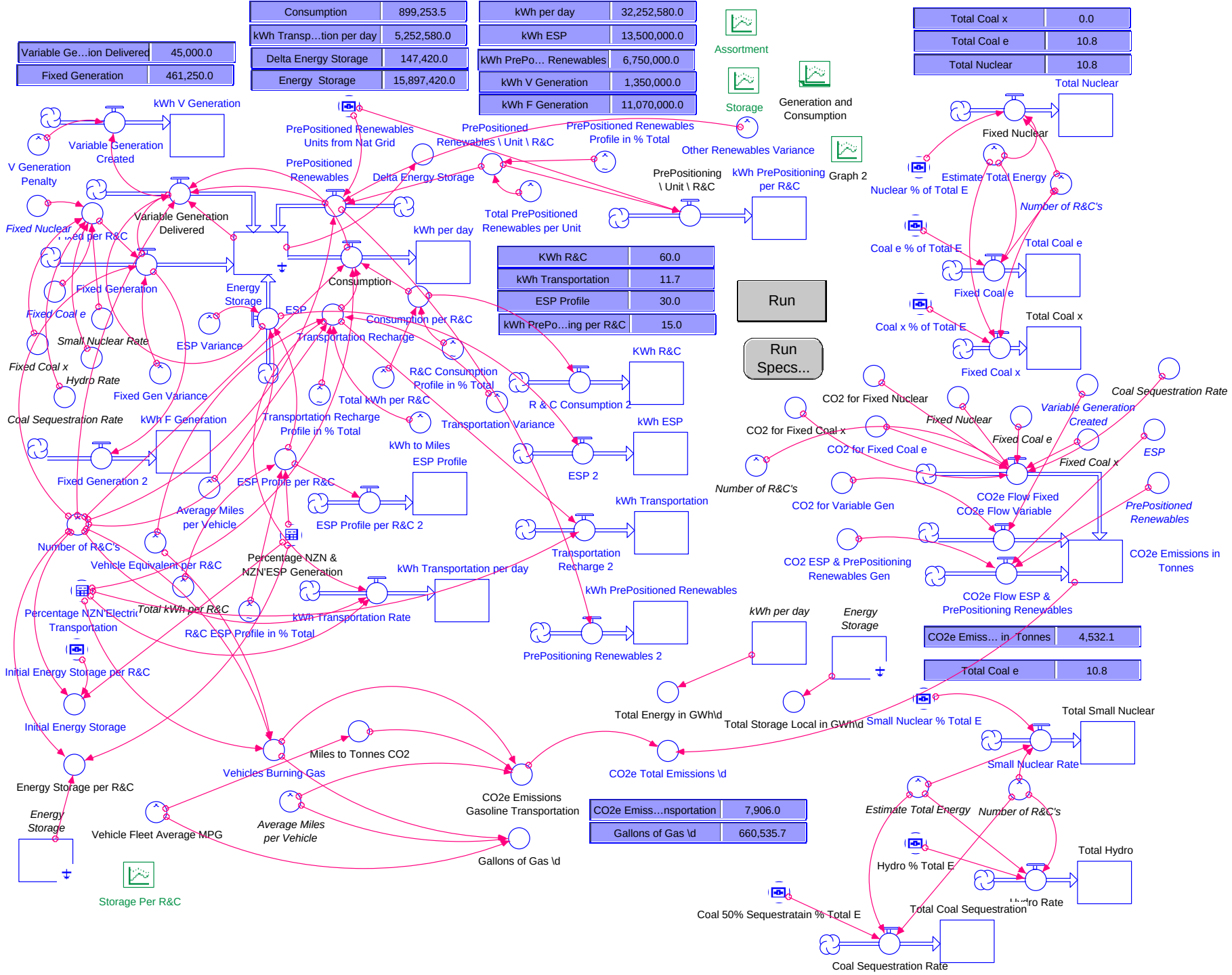
Run

Initial Energy Storage per R&C

0 — 100 — U — 70

Delta Energy Storage	147,420.0
Energy Storage	15,897,420.0

Storage Per R&C


Consumption 899,253.5
kWh Transp…tion per day 5,252,580.0
Delta Energy Storage 147,420.0
Energy Storage 15,897,420.0
kWh per day 32,252,580.0
kWh ESP 13,500,000.0
kWh PrePo… Renewables 6,750,000.0
kWh V Generation 1,350,000.0
kWh F Generation 11,070,000.0
Variable Ge…ion Delivered 45,000.0
Fixed Generation 461,250.0
Total Coal x 0.0
Total Coal e 10.8
Total Nuclear 10.8
Assortment
Storage
Generation and Consumption
Graph 2
kWh V Generation
Variable Generation Created
V Generation Penalty
PrePositioned Renewables Units from Nat Grid
PrePositioned Renewables \ Unit \ R&C
PrePositioned Renewables Profile in % Total
Other Renewables Variance
PrePositioned Renewables
Delta Energy Storage
PrePositioning \ Unit \ R&C
kWh PrePositioning per R&C
Total PrePositioned Renewables per Unit
Fixed Nuclear
Fixed per R&C
Variable Generation Delivered
kWh per day
Fixed Generation
Energy Storage
Consumption
Fixed Coal e
ESP
Consumption per R&C
Small Nuclear Rate
ESP Variance
Transportation Recharge
Fixed Coal x
Hydro Rate
Fixed Gen Variance
R&C Consumption Profile in % Total
Total kWh per R&C
Coal Sequestration Rate
kWh F Generation
Transportation Recharge Profile in % Total
Transportation Variance
kWh to Miles
ESP Profile
Fixed Generation 2
ESP Profile per R&C
Average Miles per Vehicle
ESP Profile per R&C 2
Number of R&C's
Vehicle Equivalent per R&C
Percentage NZN & NZN'ESP Generation
Percentage NZN'Electri Transportation
Total kWh per R&C
R&C ESP Profile in % Total
kWh Transportation Rate
kWh Transportation per day
Initial Energy Storage per R&C
Initial Energy Storage
Energy Storage per R&C
Energy Storage
Storage Per R&C
Vehicle Fleet Average MPG
Average Miles per Vehicle
Vehicles Burning Gas
Miles to Tonnes CO2
CO2e Emissions Gasoline Transportation
Gallons of Gas \d
KWh R&C 60.0
kWh Transportation 11.7
ESP Profile 30.0
kWh PrePo…ing per R&C 15.0
Run
Run Specs...
KWh R&C
R & C Consumption 2
kWh ESP
ESP 2
kWh Transportation
Transportation Recharge 2
kWh PrePositioned Renewables
PrePositioning Renewables 2
kWh per day
Energy Storage
Total Energy in GWh\d
Total Storage Local in GWh\d
CO2e Total Emissions \d
CO2e Emiss…nsportation 7,906.0
Gallons of Gas \d 660,535.7
Total Nuclear
Fixed Nuclear
Estimate Total Energy
Nuclear % of Total E
Number of R&C's
Coal e % of Total E
Total Coal e
Fixed Coal e
Coal x % of Total E
Total Coal x
Fixed Coal x
CO2 for Fixed Nuclear
Coal Sequestration Rate
Variable Generation Created
Fixed Nuclear
CO2 for Fixed Coal x
Fixed Coal e
CO2 for Fixed Coal e
ESP
Fixed Coal x
Number of R&C's
CO2 for Variable Gen
CO2e Flow Fixed
CO2e Flow Variable
PrePositioned Renewables
CO2 ESP & PrePositioning Renewables Gen
CO2e Emissions in Tonnes
CO2e Flow ESP & PrePositioning Renewables
CO2e Emiss… in Tonnes 4,532.1
Total Coal e 10.8
Small Nuclear % Total E
Total Small Nuclear
Small Nuclear Rate
Estimate Total Energy
Number of R&C's
Hydro % Total E
Total Hydro
Hydro Rate
Total Coal Sequestration
Coal 50% Sequestratain % Total E
Coal Sequestration Rate

Net-Zero-Neighborhood Simulation, R&C only: Metro like Knoxville: 450,000 residential and commercial

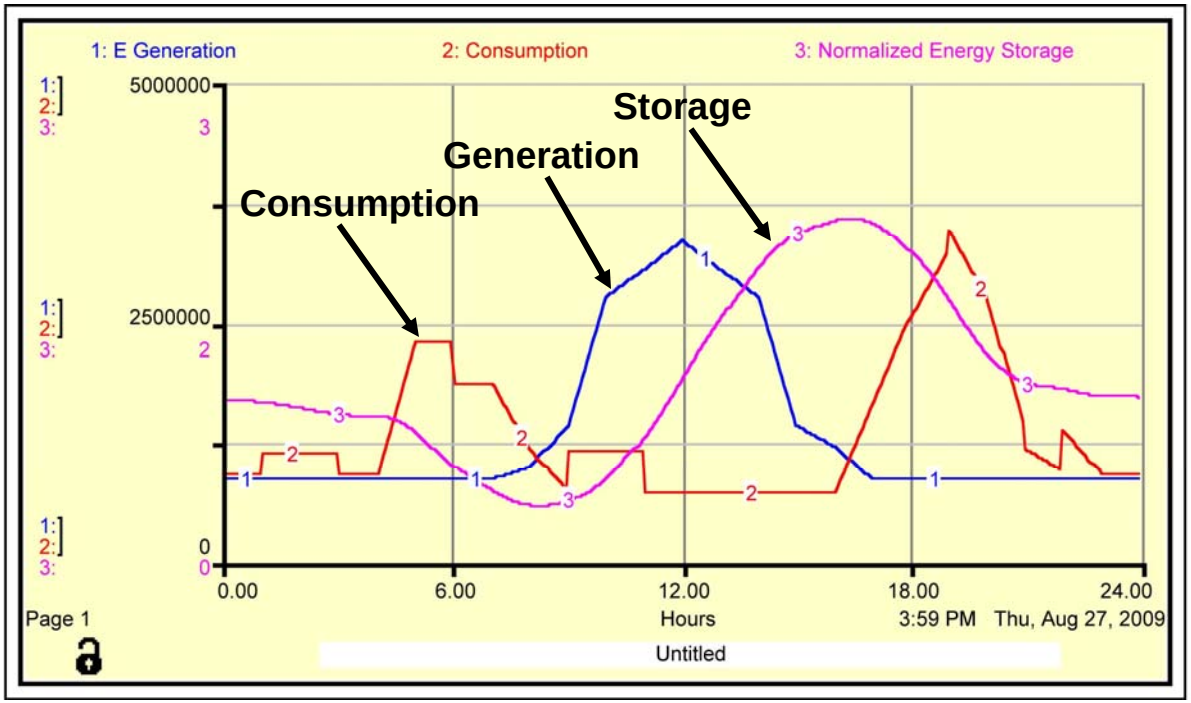
	2010	2030
NZN Generation	No	Yes = 50% ~ 30 kWh/R&C
Pre-Positioning Energy	No	Yes ~ 15 kWh/R&C
NZN All-Electric Vehicles	No	Yes = 50%
Fleet MPG	24.6	28.0
CO2e (electric gen), tonnes/d	19,700	4,300
CO2e (transportation), tonnes/d	17,500	7,900
Total CO2e, tonnes/d	37,200	**~ 67% drop** **12,200**
Gallons of gasoline (gallons)	1,500,000	**660,000**
Total energy/day (GWh)	27 GWh	32 GWh

Small Storage Case

50% market share

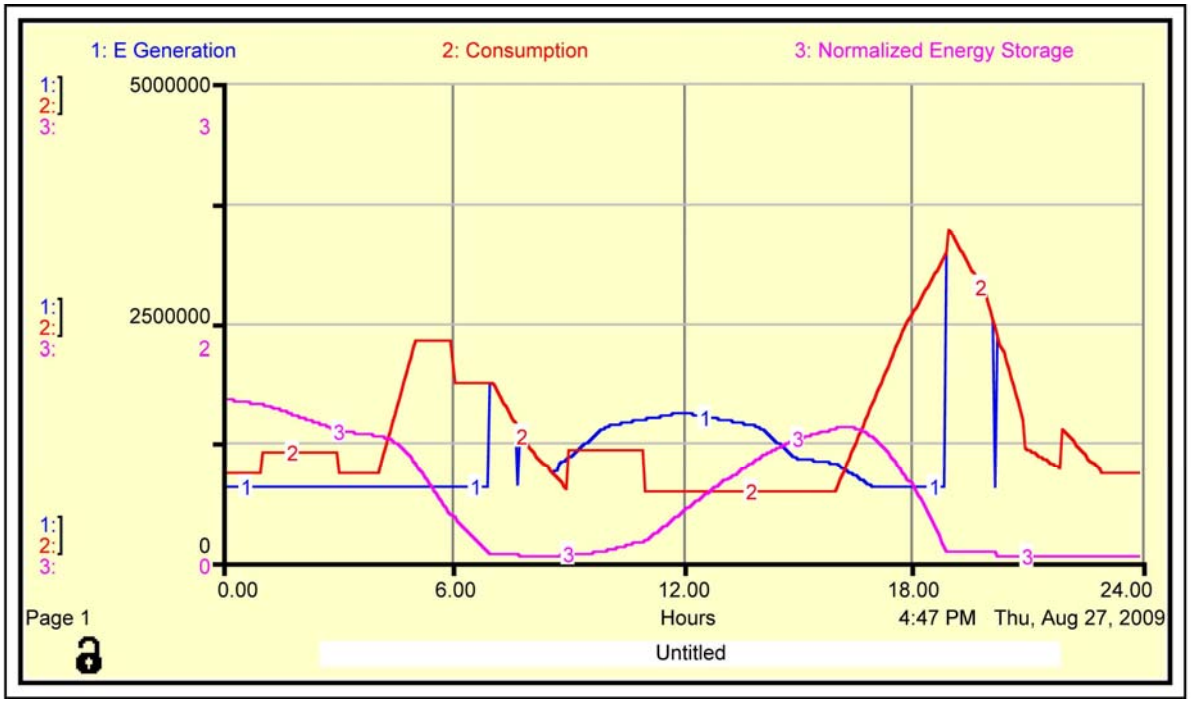
Good Day for NZN

100% NZN Generation
~ 30 kWh/NZN_player start
CO2e ~ 4500 tonnes



Poor Day for NZN

25% NZN Generation
~ 20 kWh/NZN_player start
CO2e ~ 9600 tonnes



Key Results of NZN

- Local storage breaks “use it or loose it” dependency between generation and demand
  - all energy generation regardless of timing or location behave as 24 hr/day base load
- Coupling transportation and local storage creates a mobile electrical grid that operates in public, private, and national interests
  - e.g., creates point-to-point mass transit
  - e.g., powers homes and businesses through peak demands, transients, interruptions, and outages
  - e.g., creates robust, reliable grid whether civil or national defense related
  - e.g., reduces CO2e emissions and oil imports
- “Tagging” energy will drive energy to commodity status, create a consumer marketplace, and drive creation of local jobs
  - Enables widespread multi-source market for energy

500-Mile Battery

- Key and critical enabler for local-consumer generation
- Size would be between 300-500 kWh
  - Standardized---works in either fixed or mobile; ubiquitous infrastructure
  - Commodity---mass market; commodity pricing
- Integral part of local smart-grid
  - Shared national infrastructure---energy storage in proportion to population for all renewables generation; national security---many robust islands;
  - Local mission---net-zero neighborhoods; zero emissions transportation; low income incentives
- Pre-position energy for peak load and other anticipated transient demands such as weather
- Great commodity size for scaling in consumer residential, commercial, and industrial (e.g., 1/3-1/2 MWh)

TESLA Motors

Asked the following question?

Change the game so that EVs are the compelling, irresistible option for transportation?

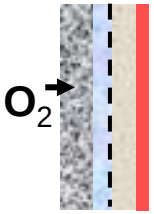
Reduce the cost of the battery

Increase the energy density of the battery

Marc Tarpenning, co-founder of Tesla Motors

Initial Technical Focus and Goals

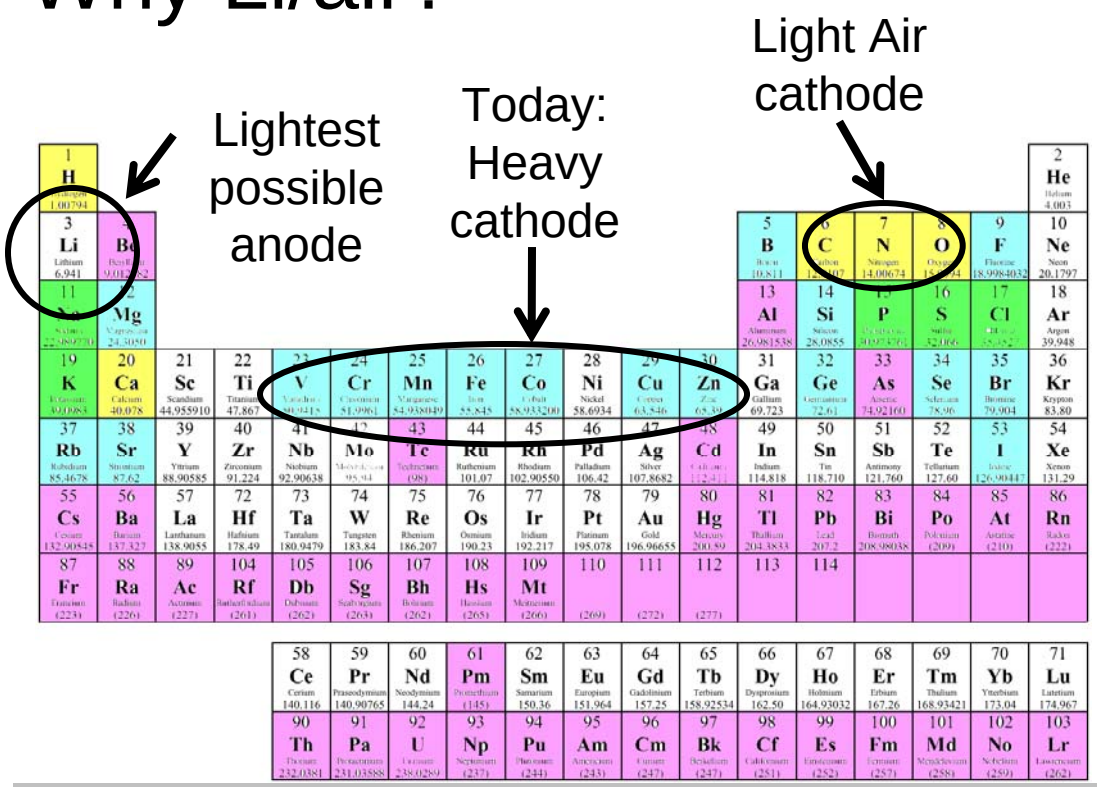
---A starting point



- *Li-air batteries*
  - *reversibly react Li-ions with atmospheric oxygen*
- Advantages: light weight, very high energy density
  - comparable to gasoline
  - alternative to infrastructure challenges of H_2 and fuel cells *
- Goal: practical energy density of 2000 Wh/kg
  - *Exceed usable* energy density of gasoline power trains.
  - Current Li-ion batteries are 100-200 Wh/kg.
- Lithium/Air is rich in unexplored science
  - Need to plan for a multi-year, deep science, technology, and innovation project

* However, certain versions of Lithium/Air can benefit from existing fuel cell research.

Why Li/air?



Cell Specs	
Chemistry: Aprotic Li/Air	
Energy Density	**2 kWh/kg**
Weight charged/discharged	**40/60 g**
Peak Current	**25 A**
Discharge Voltage	**2.5V**
Internal current density	**6.8 mA/cm^2**
Peak airflow @ 20% air / 4% O_2 utilization	**80 ml/sec**
Capacity	**80 Wh**
Active amount of Lithium	**8.4g / 21%**

- Energy content
  - Gasoline: 13,000 Wh/kg
  - Li/air: (3.05 V x 96500 C)/(3600 s x 7 g) = 11,680 Wh/kg
- Efficiency (tank or battery to wheel):
  - Gasoline car: 13% (2008 APS study on Energy)
  - Electrical car: 88%

- *Usable* energy content
  - Gasoline: 13,000 x13% = 1.6 kWh/kg
  - Li/air: 11,680 x 50% (practical) x 0.88 = 5.1 kWh/kg

50% Efficient Solar Cell

- Key and critical enabler for local-consumer generation
  - Absolutely essential if there is any hope of taking residential off the grid
- Scalable system but generally the base size would be about 220 sq.ft
  - 4’ x 8’ panels; about 50% efficient panels
  - System---6 or 7 panels; inverter; and connector---can provide electricity about equal to the consumption for an average U.S. home in southeastern location
  - System at commodity pricing = $2000
- Nano-Scale R&D – the affects are at quantum scale
  - Quantum scale affects that drive multiple electrons per photon
  - Nanotubes to achieve larger conductivity of electrons out of the base material

Initial pathway to 50% efficient solar cells

- Reports ultra-efficient multiple exciton generation (MEG) for single photon absorption in colloidal PbSe and PbS quantum dots

- Introduces a new model for MEG based on the coherent superposition of multiple excitonic states.

NANO LETTERS

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Letter

Highly Efficient Multiple Exciton Generation in Colloidal PbSe and PbS Quantum Dots

Randy J. Ellingson, Matthew C. Beard, Justin C. Johnson, Pingrong Yu, Olga I. Micic, Arthur J. Nozik, Andrew Shabaev, and Alexander L. Efros

Nano Lett., **2005**, 5 (5), 865-871• DOI: 10.1021/nl0502672 • Publication Date (Web): 30 March 2005

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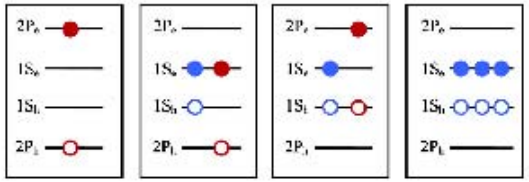

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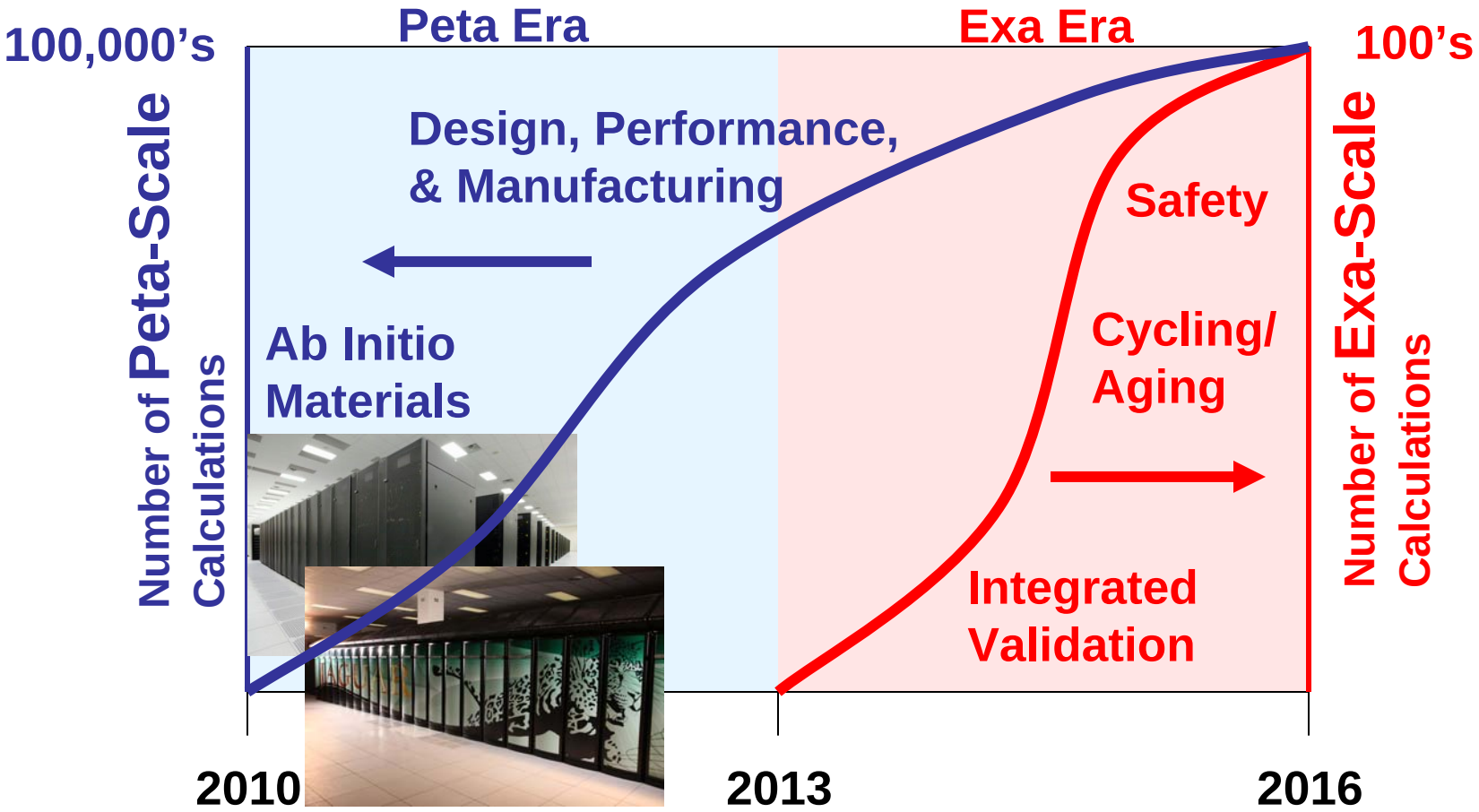
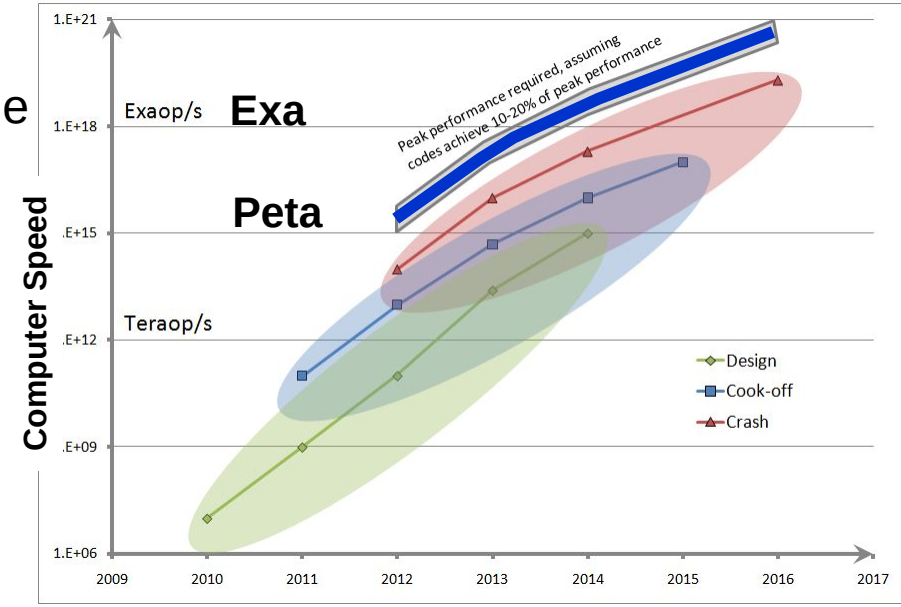
Battery500 & Photovoltaic50 Science-Based Requirements



Required Code Suites—Battery500

- Materials (ab initio)
  - Polymer electrochemistry
  - Catalysis
  - Solubility
  - Electrode / Anode
- Design/ Performance
  - Charge
  - Storage
  - Discharge
  - Cycling/Aging
- Safety
  - Crash
  - Thermal insult
  - Puncture/penetrations
  - Thermal runaway
- Manufacturing
  - Vapor deposition
  - Thin film process control
  - Structural integrity

Systems Engineering And Manufacturing



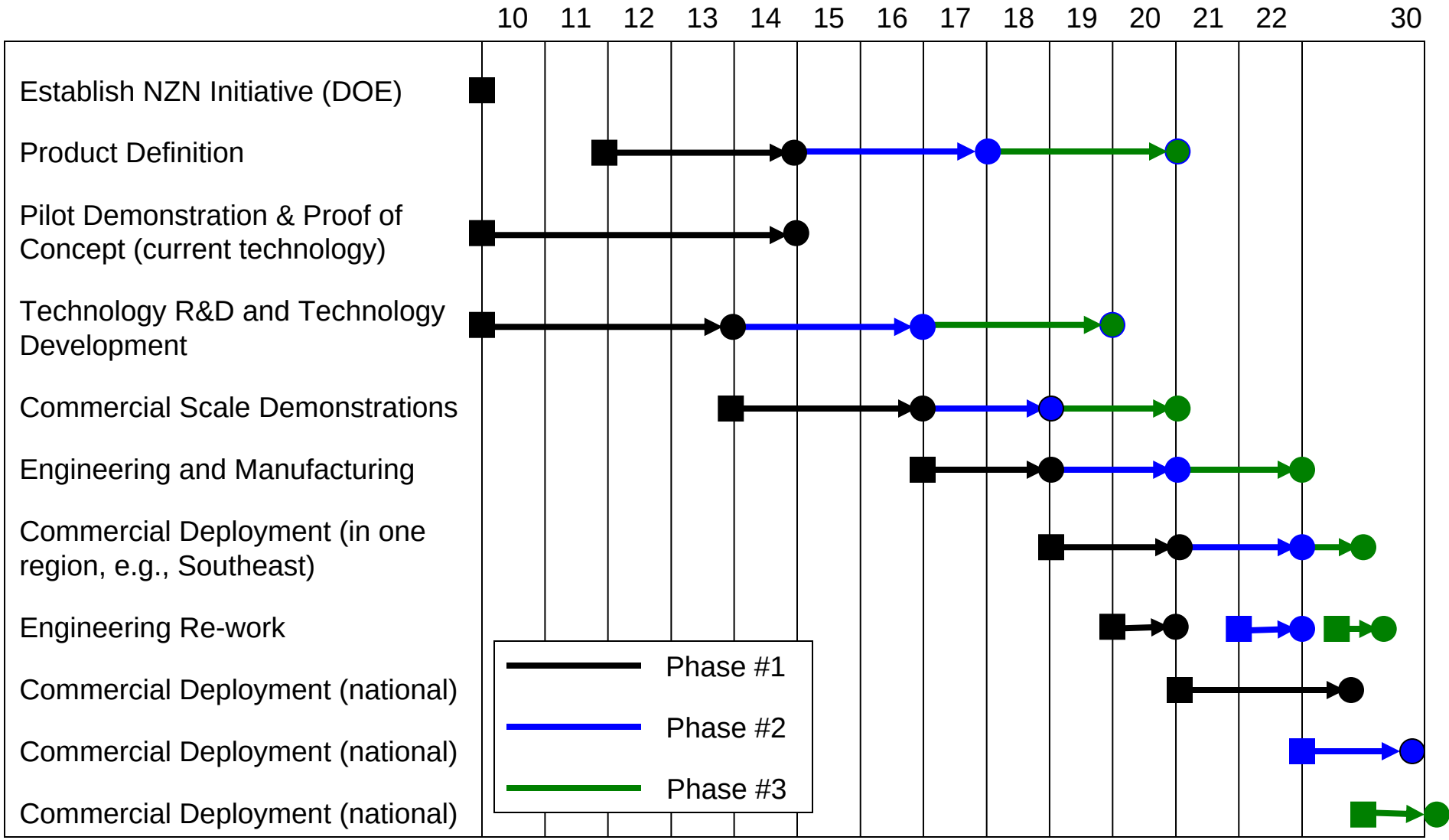
2013

NZN can be a commercial enterprise by 2020

NZN can achieve both significant CO_2e and imported oil reductions by 2030

- Proof-of-Concept demonstrations can begin immediately with current technology
- All relevant technology can be demonstrated by 2016, provided that key R&D is started in 2010
- Demonstrations of commercial viability and systems engineering can be completed by 2020
- Full scale commercial availability and implementation can begin by 2020

A Time Table For The Net-Zero-Neighborhood Plan for Achieving 2030 Goals



What are the enablers?

- Local Storage (must be at point of consumption)
- Tag/label energy
- 500 mile battery
- Commodity, standardize “battery” technology, whether for transportation or consumer products
- 50% efficient solar PV cells
- Preposition energy in local storage
- Consumer products for residential and commercial generating energy; standardize infrastructure; energy star ratings and certification

Ask

- Your “no-holds-barred” view of the Net-Zero Neighborhoods Plan
- If you like the Net-Zero Neighborhoods Plan concept help us get it
  - National energy and information conferences/summits