Grid Futures through Scenario Planning

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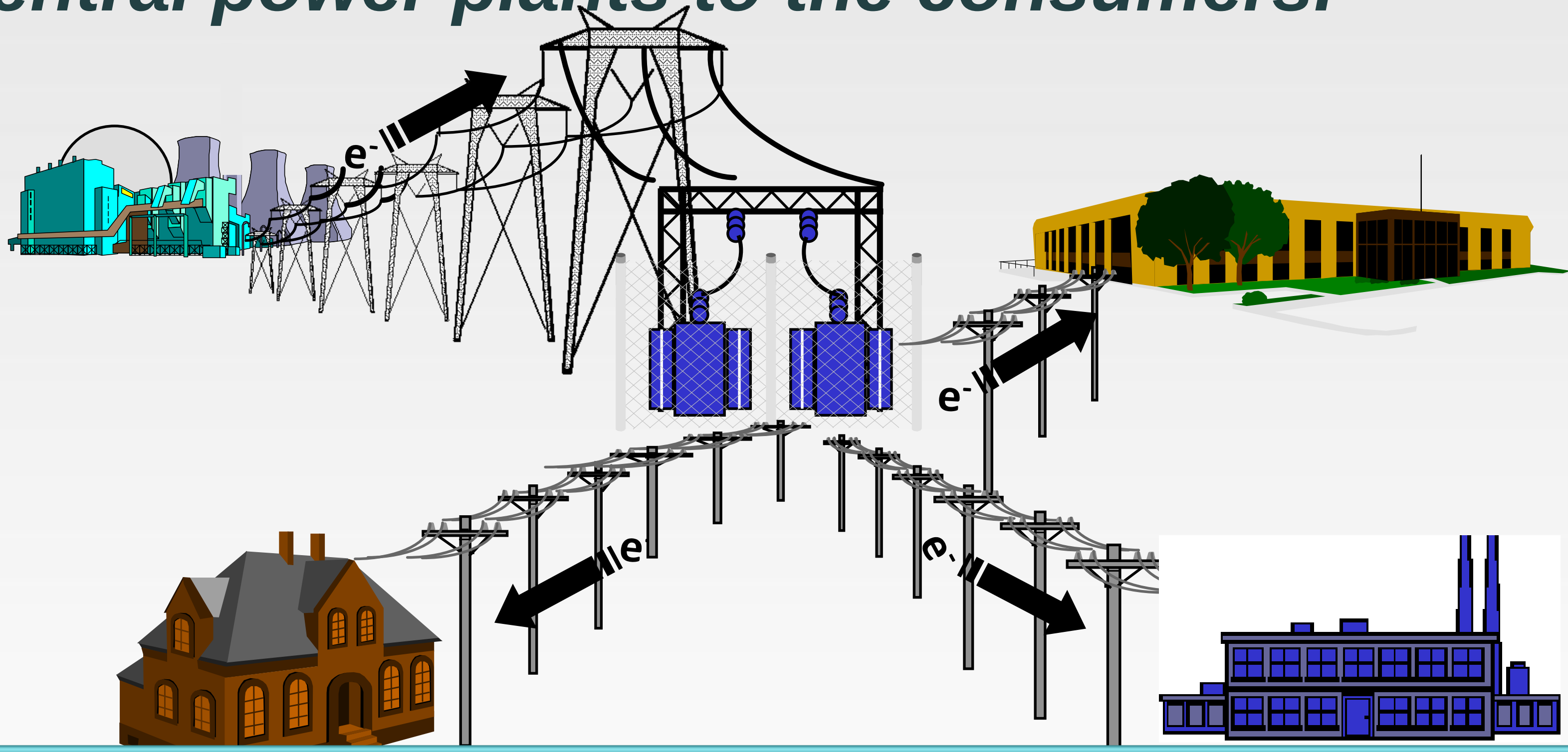
For most of the 20th Century, the electric grid had a relatively simple role: moving electricity from central power plants to the consumers.



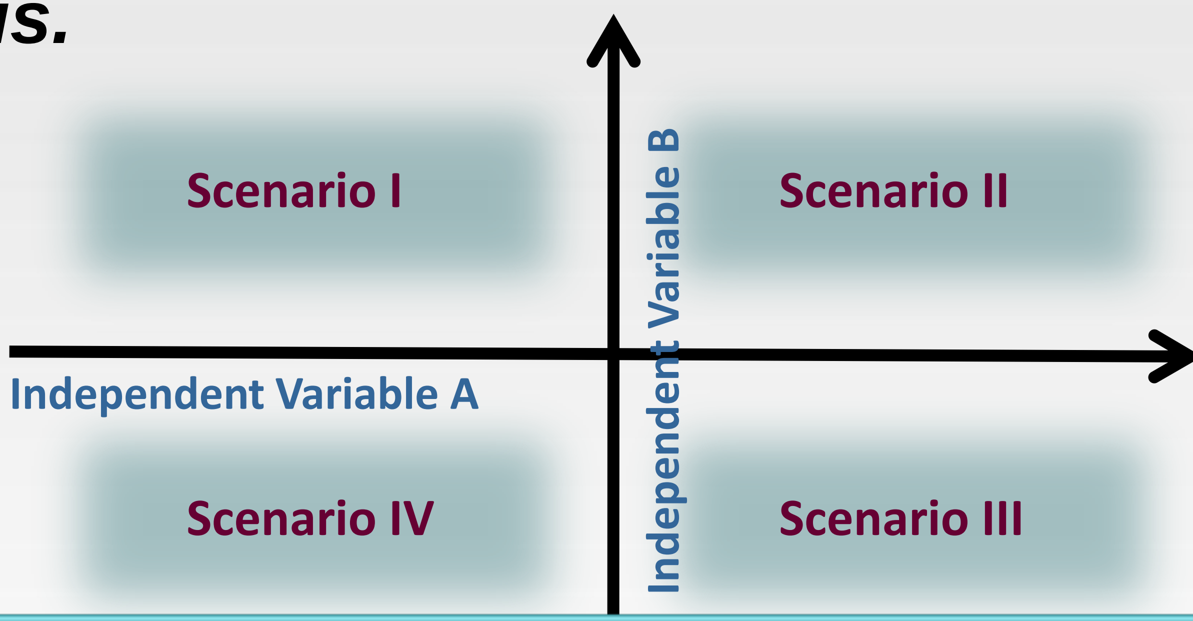
Its behavior was predictable, operation was largely deterministic, and an operator was in control.

But the 21st Century electric grid operator faces:

- A growing tension between reliability and cost
- Aged underbuilt infrastructure strained to the limits; new infrastructure increasingly difficult to site and permit
- Inadequate situational visibility of grid for operators
- The threat of extremely expensive and disruptive wide-area blackouts, and increased enforcement of operations standards.
- Accommodating the uncertainty of electric markets in planning and operation, and a growing and changing electric customer base.
- Complying with economic and public policy pressures, especially concerning environmental impacts and regulations, increased use of renewable generation, and protecting grid security and customer privacy.

Given this growing uncertainty, complexity, inadequacy, & conflict, what will the future grid look like?

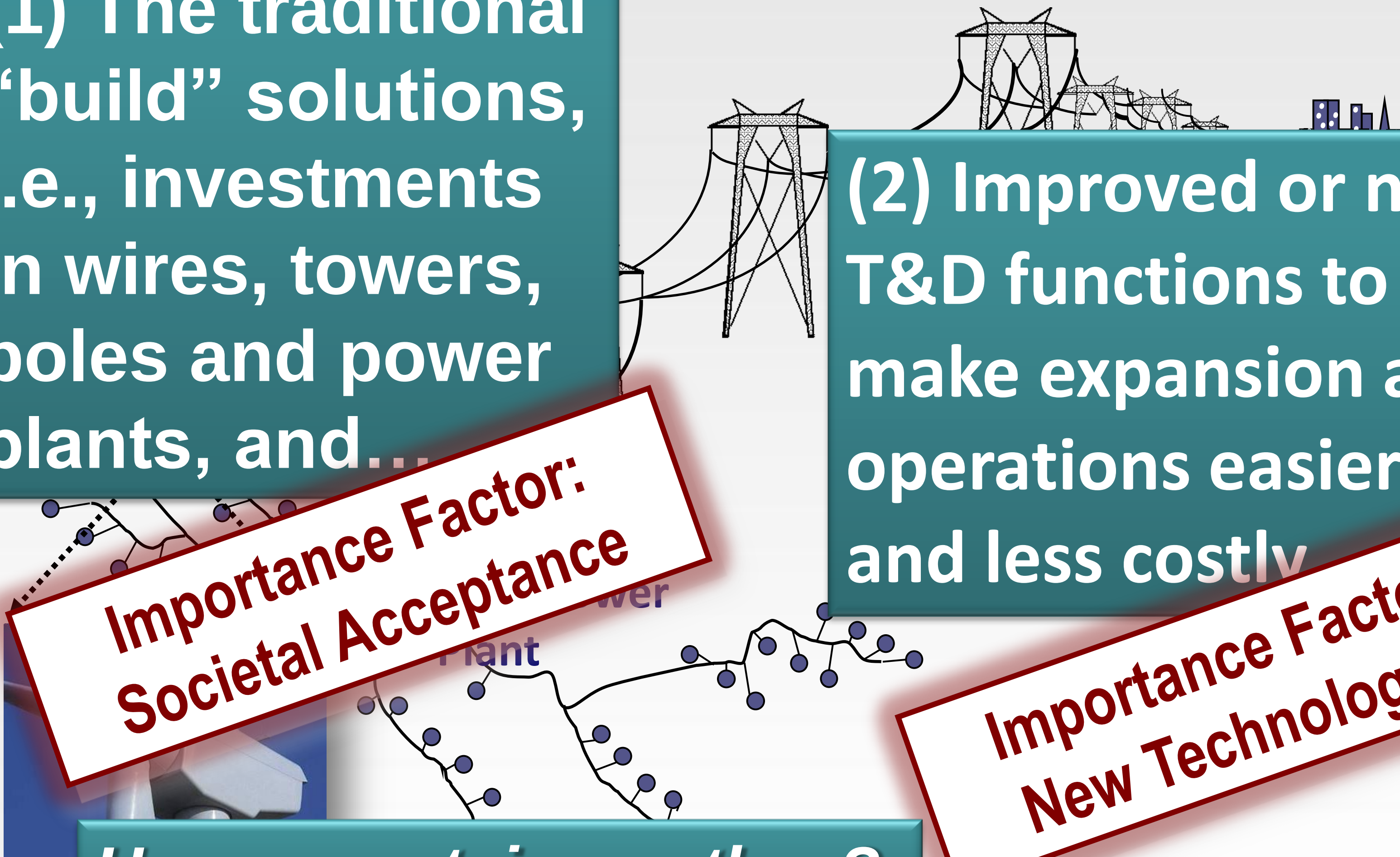
We explore the future of electric transmission and distribution systems through scenario planning analysis.



Different plausible futures are the logical implications of cause & effect interactions in each quadrant between two highly uncertain variables. But which two?

For successful expansion and operations of T&D, there are essentially two options :

(1) The traditional "build" solutions, i.e., investments in wires, towers, poles and power plants, and…



Importance Factor: Societal Acceptance

(2) Improved or new T&D functions to make expansion and operations easier and less costly

Importance Factor: New Technologies

How uncertain are they?

Two Extremes of the T&D Technological Continuum Future

Incremental Improvements:

T&D functionalities improve only incrementally because new technology:

- Development encounters intrinsic physical difficulties
- Is used to "patch" the old infrastructure because it cheaper & easier
- Is too risky for T&D owners, operators, investors and regulators

Paradigm Shifts:

T&D functionalities substantially improve because new technologies cost-effectively enable:

- Improved access for new generation by putting new T&D lines in a "better light."
- Accommodating unique generator and demand behavior through a smarter and more flexible grid
- Increased T&D capacity by optimizing the grid for greater power flow.

Assertion: Degrees of T&D Technology development and adoption are highly uncertain.

Two Extremes of the Societal Continuum Future

Society Resists T&D Build-out

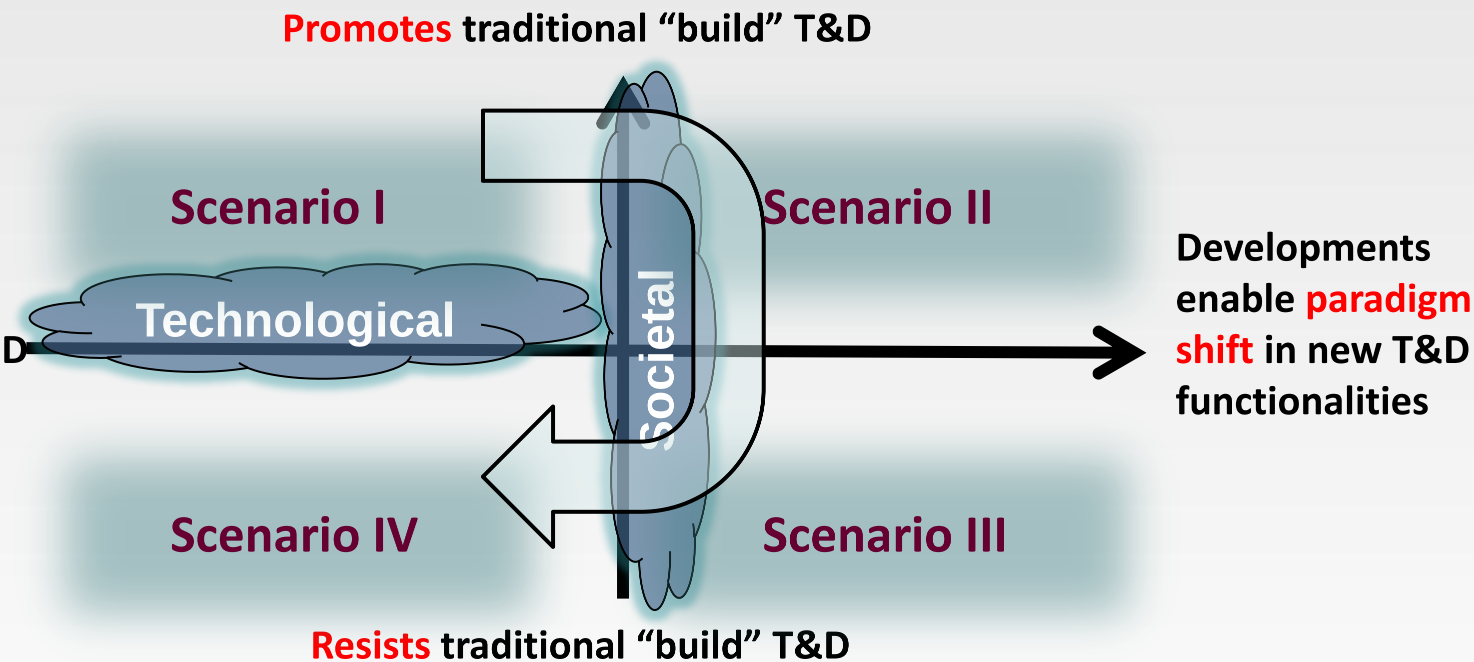
- Permitting of transmission projects takes longer or doesn't happen.
- Cost/benefit allocations contested/prolonged.
- Pressure to keep down infrastructure costs.
- Incentive tariffs and regulations for demand response, energy efficiency and/or distributed generation succeed.

Society Promotes T&D Build-out

- Concerns about power outages, congestion costs, national security and economic health lead to more use of eminent domain, pro-T&D legislation and/or tolerance for T&D projects .
- Incentive tariffs and regulations for demand response, energy efficiency and/or distributed generation fall short.

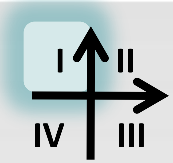
Assertion: The balance among the Societal decisions for economic health, environmental protection and energy security is highly uncertain.

Interactions between the 2 axes of uncertainty – societal policies & norms and technology developments & use – form 4 scenarios.



Starting with Scenario I, we examined the "role," "operations," "form" and major "success factor" for each scenario.

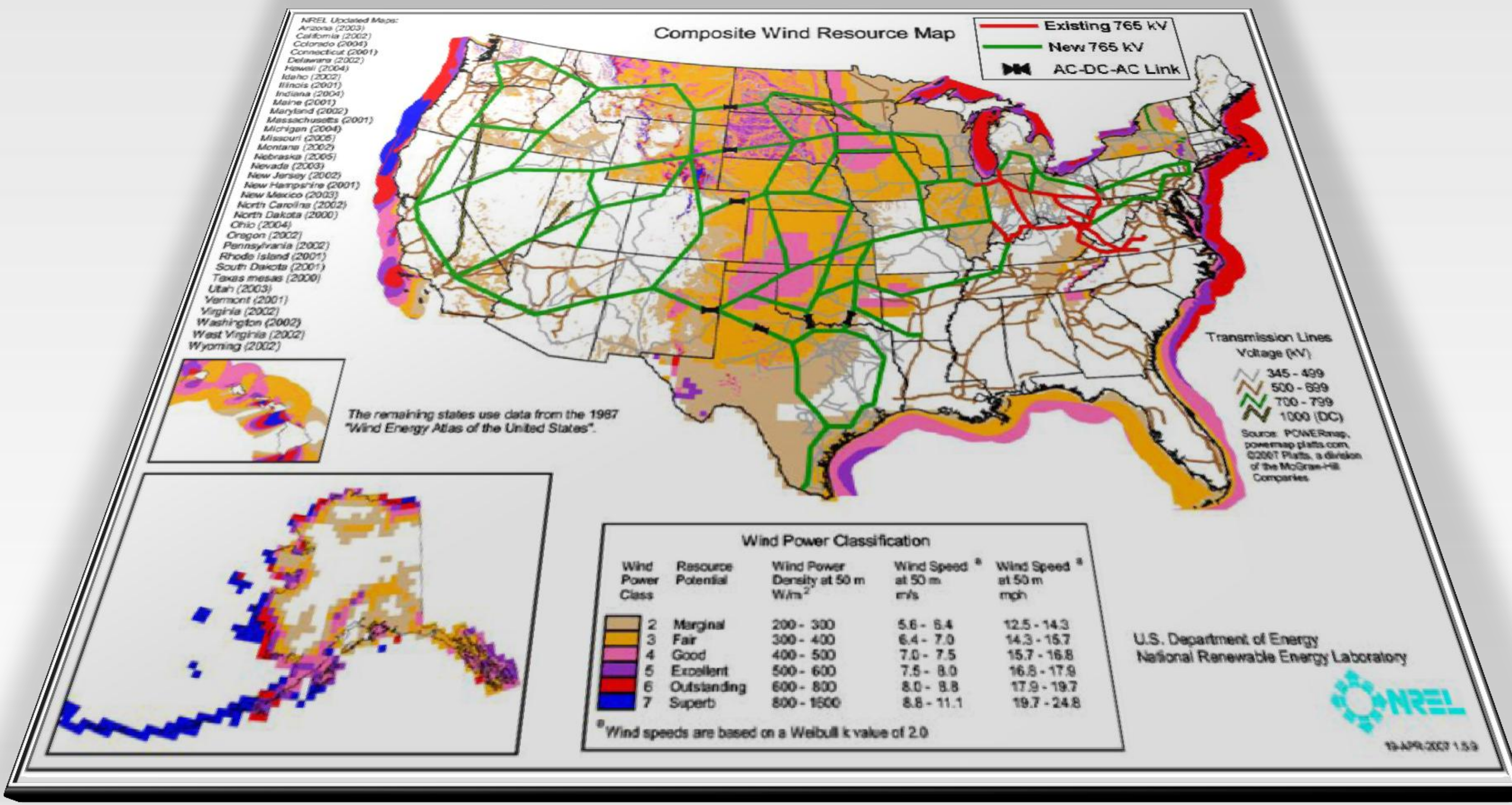
I. The "Beefy" T&D Infrastructure



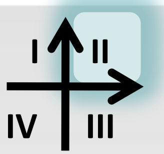
- **Role – Same as "Legacy Grid"**
  - To deliver and market significant amounts of electricity generated by central station power plants.
- **Operations – Same as "Legacy Grid"**
  - Smart grid largely limited to situational awareness for reliability, and business market transactions among generators and consumers.
- **Form – Much more of the "Legacy Grid" → "Metallic Sky"**
  - Wires, towers and poles make a visible presence.
  - Wind in the central and solar in the southwest U.S. lead to "interstate highway" high voltage grid.
  - Demand response & distributed generation limited by inflexible grid
- **Success Factor: Building Infrastructure**

Caveat: AC instability resulting from large power transfers over long distances could cap growth of system.

The "interstate highway" high voltage grid might be a sign of the "Beefy" grid.



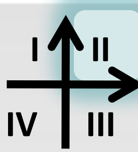
II. The “Nimble” T&D Infrastructure



- **Role – Same as “Legacy Grid” but w/ “Finesse”**
  - To deliver and market electricity generated by a broad spectrum of central station and distributed resources.
- **Operations – The “Optimized Legacy Grid”**
  - Smart grid used for “command and control,” increasing roles of demand response, EVs, power flow control, etc.
  - Optimized to reduce costs and improve services
- **Form - more of the “Legacy Grid” but no “Metallic Sky”**
  - Wind in the central and solar in the southwest U.S. lead to “*smart* interstate highway” high voltage grid.
  - Temporal (storage) and power flow controls used for grid support/stability
  - Distributed generation accommodated by flexible and resilient distribution system.
- **Success Factor: Flexible Service**

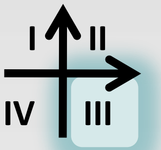
Motto: “Deliver a kWhr from anywhere to anyone at anytime.”

In the "Nimble" scenario, distributed generation emerges and sends power upstream.



Optimized operations via technology means fewer wires & towers.

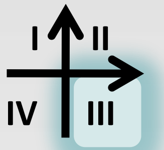
III. The "Radical" T&D Infrastructure

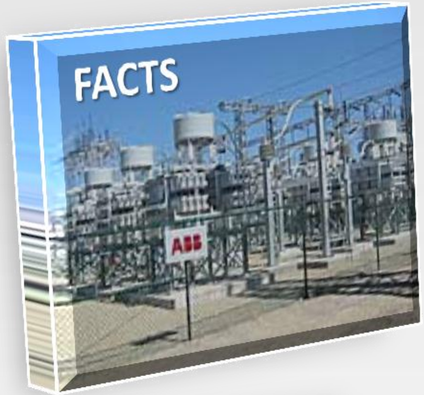


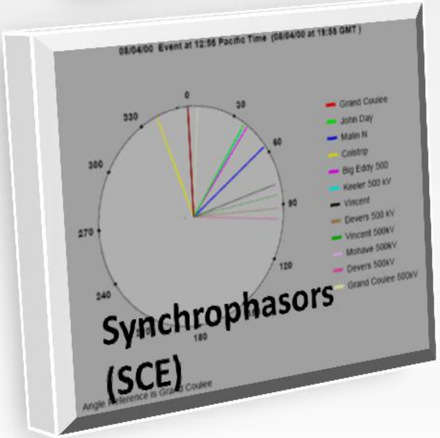
- **Role – Full-Spectrum Service**
  - To deliver and market electricity generated by some central station and significant numbers of distributed power plants.
  - Generators and consumers are clients of T&D services.
- **Operations – "Tricky"**
  - Smart grid used for "command and control," heavy roles for demand response, EVs, time (storage) & power flow controls, etc., and optimization of supply, demand and grid assets.
- **Form – Local and Regional Networks**
  - Underground transmission, compact design, dynamic ratings, etc., are in a "horse race" with distributed generation, demand response and microgrids.
  - Time (storage) and power flow controls used for grid support and optimized utilization
- **Success Factor: Intelligent Microgrids/New Transmission Tech**

The grid "body" has a "legacy look" on the outside with a "radical mind & sole" inside.

The “Radical” scenario is about technology and complicated operations and services.

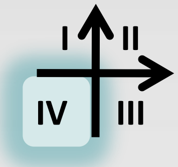






Scenario III might be the scene of a contest between the “invisible T” and the “microgrid.”

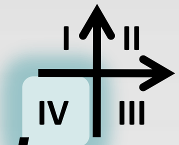
IV. The “T-Rex” “T&D” Infrastructure

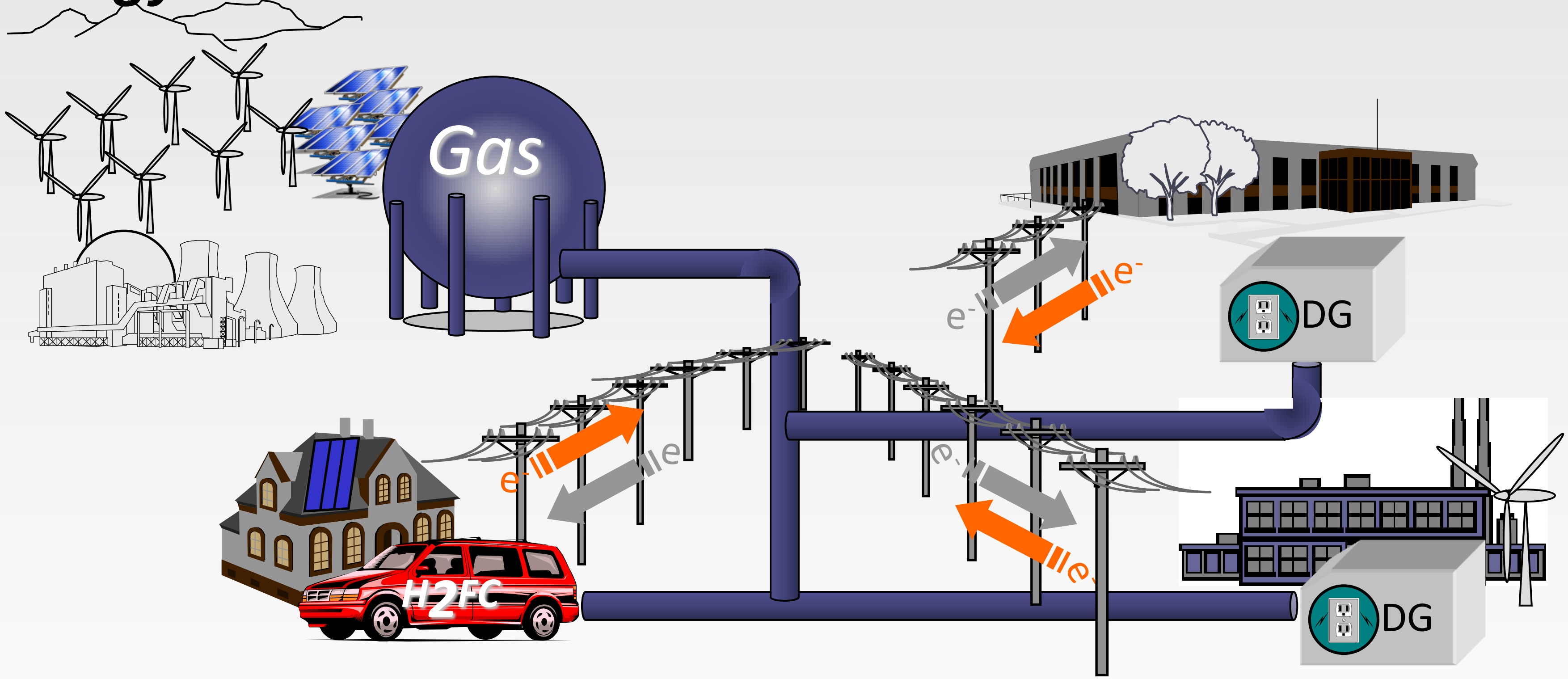


- Role – Support a Local Electric Market
  - To market and deliver electricity at the “distribution” level
- Operations – Two-Way Power Flow
  - Low-voltage distribution network, with two-way flow, operated much as mini-transmissions with smart grid limited to situational awareness, supervision and control
- Form – “T-Rex” and Distribution Networks
  - Transmission becomes the “pay phone booth;” or a “dinosaur”
  - Distribution utilities, with distributed generation, especially fuel cells, connected by distribution networks
  - Electric transmission largely replaced by pipelines for fuel, e.g., shale natural gas, or hydrogen, produced by wind in the central U.S., and solar in the southwest U.S., nuclear, etc.
- Success Factor: Distribution Networks

While “T” struggles to survive, electricity production and consumption shift to “D.”

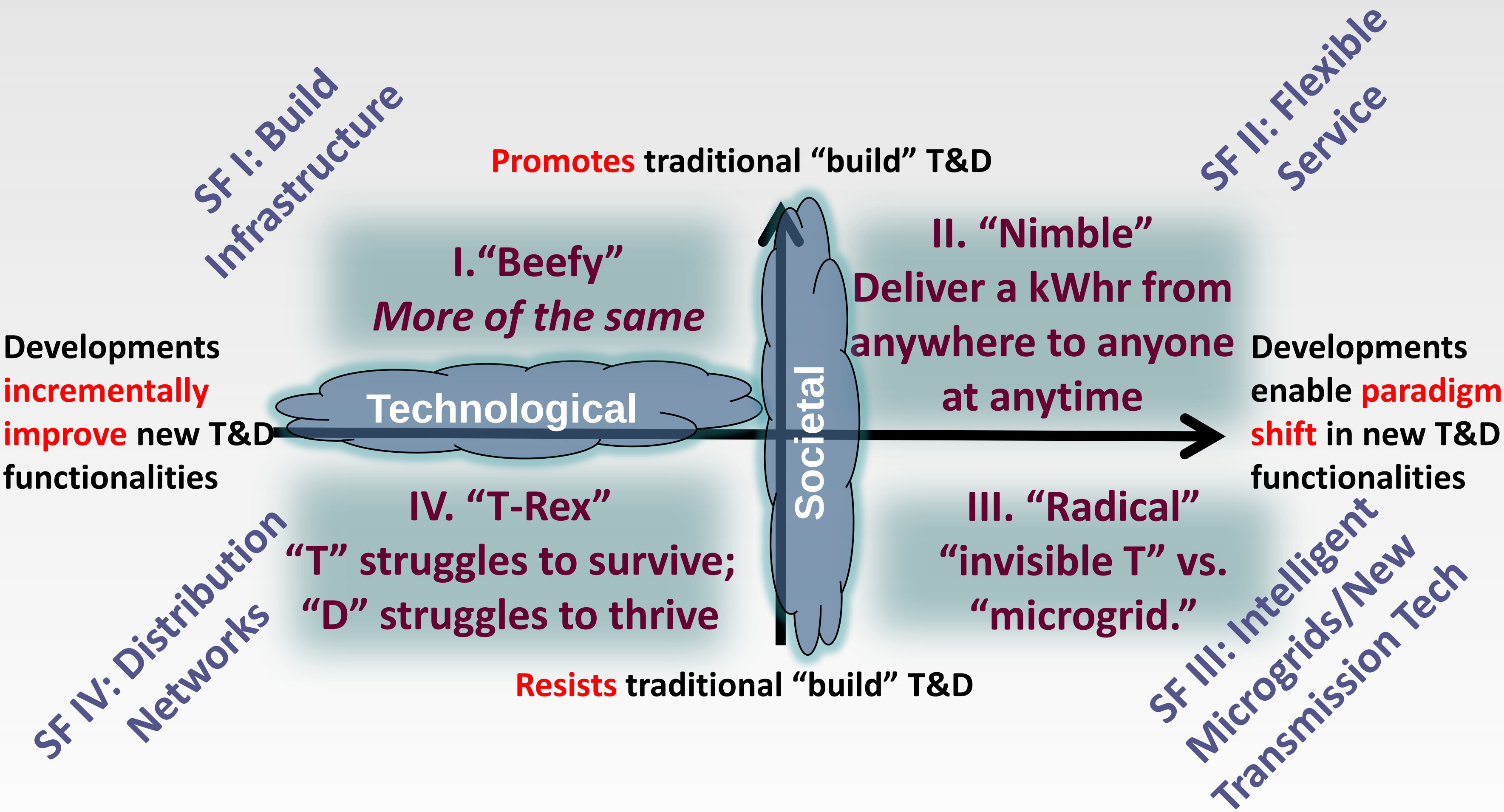
In the "T-Rex" scenario, transmission's energy delivery role gets picked up by a transportable fuel energy infrastructure.





The electricity business is transacted in distributed generation networks, i.e., mini-Ts.

The 4 scenarios summarized below.



Which scenario is happening?

Current Trends in T&D Technology and Infrastructure

- **Scenario I “Beefy”**
  - **~2000-2004, T construction ~1000 circuit miles/yr** (NERC 2012)
  - **~2005-2011, T construction ~2300 circuit miles/yr** (NERC 2012)
  - **~2011-2016, T construction ~3600 circuit miles/yr** (NERC 2012)
- **Scenario II “Nimble”**
  - **Renewables, DG, markets, EVs, DR, etc., calling for increased flexibility**
  - **New technology, e.g., AMI, PMU, DA, etc., being planned and built in T&D, but integration and applications still in question**
- **Scenario III “Radical”**
  - **Renewables, DG, markets, EVs, DR, etc., calling for increased flexibility**
  - **Recovery Act and other grants for microgrid demonstrations**
  - **Transmission permitting processes delaying construction**
  - **Transmission construction costs per mile rising**
- **Scenario IV “T-Rex”**
  - **Transmission permitting processes delaying construction**
  - **Transmission construction costs per mile rising**
  - **Natural gas supply and prices in US**

Which scenario? Beats me.

For additional information or discussion, contact :

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And he'll find someone to help you.

"People tend to overestimate what can be accomplished in the short run but to underestimate what can be accomplished in the long run." **Arthur C. Clarke**