Distributed Energy and its Revolutionary Effects on the Electricity Industry

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SCALABILITY

Industry Structure (and Regulation) Driven By Scale Economies

- Scale economies are a critical factor in determining industry structure, concentration, and regulation.

- In the past, electricity industries characterized by
    - strong economies of scale in generation,
    - extreme economies of scale in 'wires' (natural monopolies in transmission and distribution).

- As deregulation spread to electricity industries,
    - unbundling of wires, which remained fully regulated,
    - generation exposed to competition
    - incentive regulation.

New Technologies Driving Decentralization

Scale Declining

- Current electricity industry trends characterized by decentralization, digitization and decarbonization (the “three d’s”).

- Decarbonization policies are driving technological innovations that alter ‘minimum efficient scale’ in generation. (Think 800+ MW coal generator vs. 2 MW wind or 5 kW roof-top solar.)

- Digitization is facilitating integration of distributed energy resources (DERs) and decentralization of wires (think microgrids).

Other ‘Economies’

- Traditionally, in addition to economies of scale, there have been economies of
    - density
    - contiguity
    - scope
        - vertical integration (of generation, transmission and distribution)
        - horizontal – multi-utility model (e.g., natural gas and electricity).
- Decentralization and digitization is driving two ‘new’ economies
    - vertical scope economies at a much more granular level – ‘wires’ + DERs
    - the ‘network effect’ -- the ability of individual participants on the grid to interact with others for purposes of coordination and exchange.

A QUIET REVOLUTION

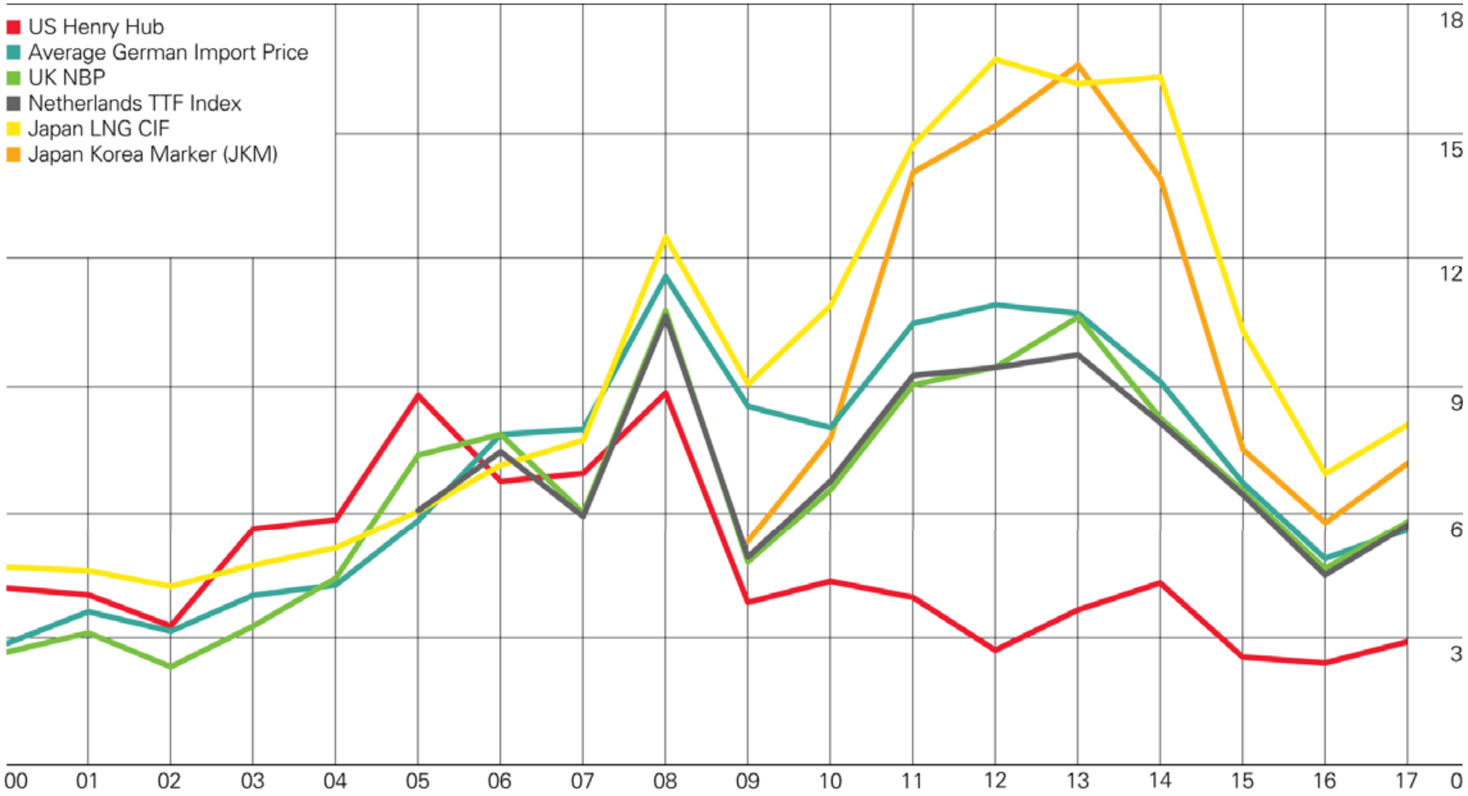
Scalability is a **Profoundly** Disruptive Force

Scalability of hydraulic fracturing is a major driving factor behind the revolution in natural gas and oil markets.

Fracking wells which cost about three *million* dollars as opposed to off-shore oil fields which cost *billions* of dollars

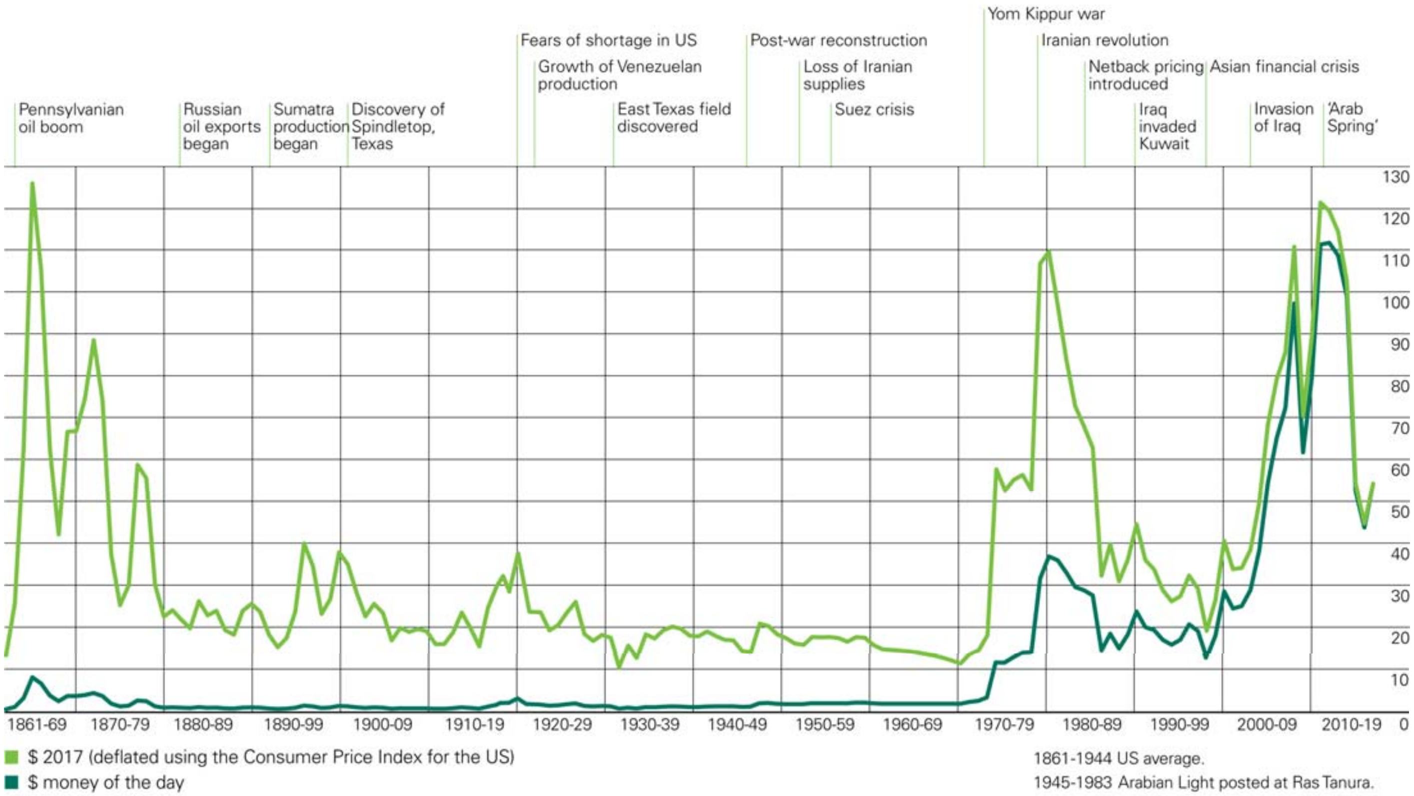
Gas prices

$/mmBtu



Crude oil prices 1861-2017

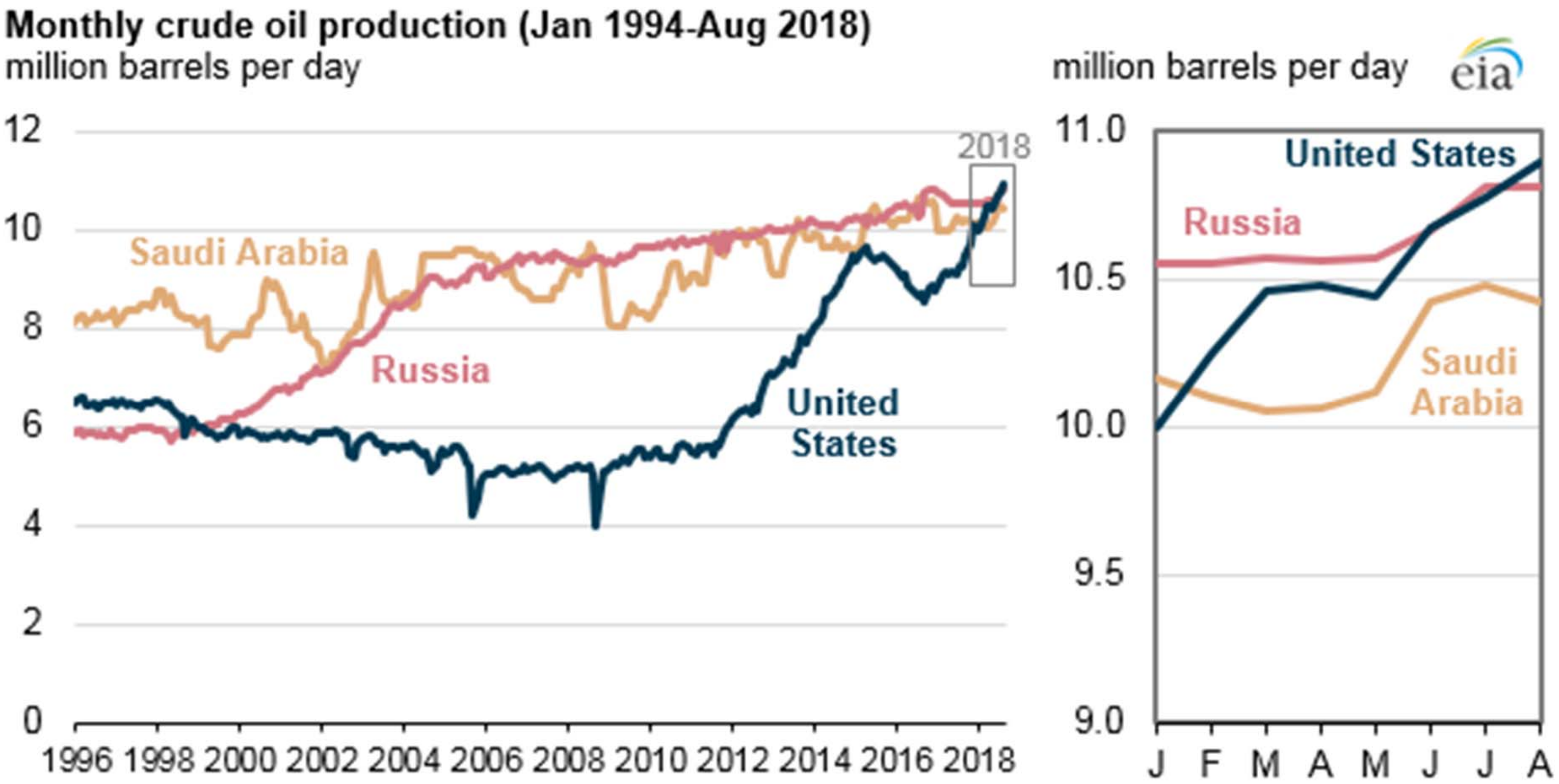
US dollars per barrel, world events



1861-1944 US average.
1945-1983 Arabian Light posted at Ras Tanura.
1984-2017 Brent dated.

The United States is now the largest global crude oil producer

U.S. EIA September 12, 2018



Impacts on Energy Markets

- Large, sustained decline in North American natural gas prices beginning in 2008.

- Dramatic drop in world oil prices beginning in 2014 with major economic impacts and political consequences.
  - Canada (dollar drops below 70 cents US; Alberta job losses)
  - Russia (value of rouble declines precipitously)
  - Venezuela (in dire financial straits)

Geopolitical Consequences

- Descendancy of OPEC
  - Efforts to bring Russia into the ‘fold’

- Rapid growth in LNG markets
  - Natural gas markets are no longer continental
  - Convergence?
  - With geopolitical consequences
    - European dependence on Russian gas
    - U.S. strategies to promote its LNG exports

Impacts on Electricity Markets

- Manitoba
  - Recent major investments in generation and transmission premised on U.S. export markets
  - Low natural gas prices constrain Manitoba export prices and contracts

- In many locations, natural gas is the ‘go-to’ generation alternative: relatively low capital costs, dispatchable, complementary to non-dispatchable generation.

NECESSITY IS THE MOTHER OF INVENTION

ENDOGENOUS TECHNOLOGICAL CHANGE

Why Did the ‘Quiet Revolution’ Occur?

- Shortage of natural gas in the U.S.

- High price of oil
  - The best cure for high prices is …. high prices

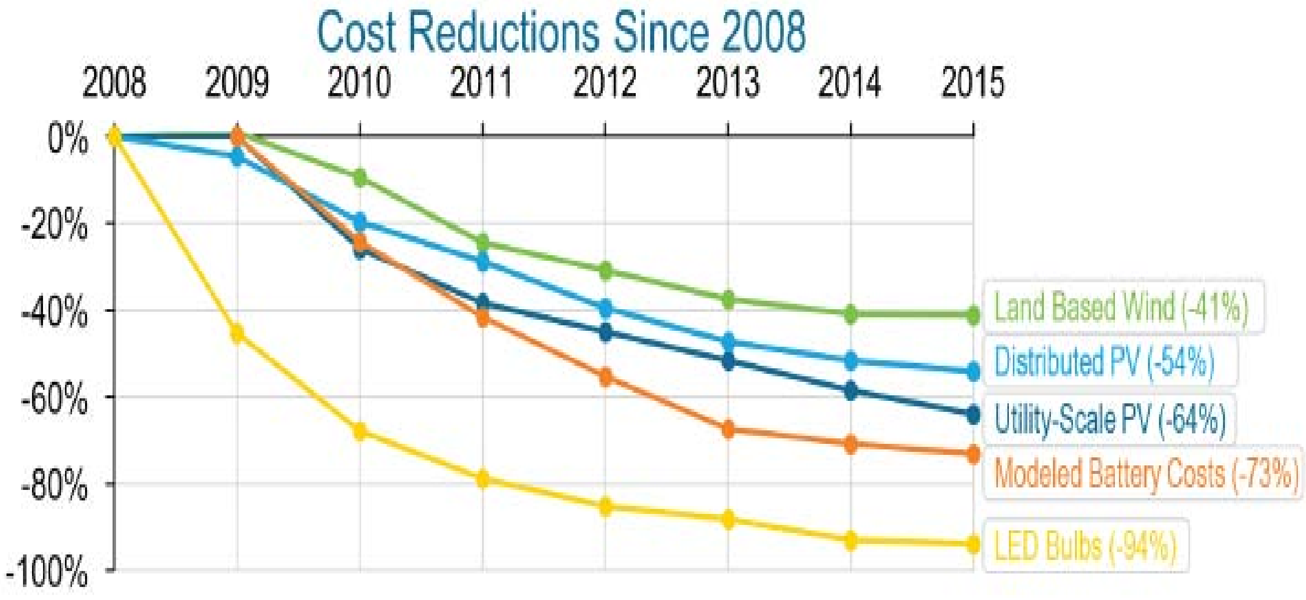
- Had OPEC maintained prices close to its long run costs of production, it is unlikely that the fracking revolution would have occurred.
  - The development of the technology was incremental, with increasing efficiency and cost reductions occurring over time.
  - Even the price collapse which began in 2014 stimulated further efficiency gains and cost reductions.

What Has Driven Innovation in Electricity?

- The need to decarbonize….

- Which in turn has led to various programs and subsidies
  - Feed-in-tariffs
  - Renewable portfolio standards
  - Government policies and regulations

New Technologies – Cost Reductions



Source: “Revolution … Now, The Future Arrives for Five Clean Energy Technologies – 2016 Update”, U.S. Department of Energy, September 2016, https://www.energy.gov/eere/downloads/revolutionnow-2016-update.

Declining Costs

- Non-dispatchable generation such as on-shore wind is priced at about 5 U.S. cents/kWh for new installations at a capacity factor of 39%.
- Solar photo-voltaic is at 7 U.S. cents/kWh at a capacity factor of 26%.
- Combined cycle natural gas electricity generation for new installations costs about 5 U.S. cents/kWh if used at high capacity (87%)
- Conventional combustion turbine generation is at about 9 U.S. cents/kWh if used at low capacity (30%).

U.S. Energy Information Administration April 2017 *Table A1a*, available at https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf.

STORAGE

Criticality of Storage

- Cost-effective, scalable storage is seen as the linchpin to overcoming two of the most pressing obstacles to decarbonizing *energy systems*:
  - the intermittency of wind and solar generation, especially as their share increases
  - decarbonization of the transportation sector.
- Chemical battery storage, at the right price point and assuming scalability, would substantially solve both problems.

Storage as Disruptive Technological Change

- The rapidity with which costs of DERs are declining suggests that we are on the cusp of disruptive changes
  - scalability is a key driver
  - this requires rethinking of utility business models and regulatory approaches.

- Disruptive innovation in regulated settings has precedent, most prominently in the telecom and information industries.

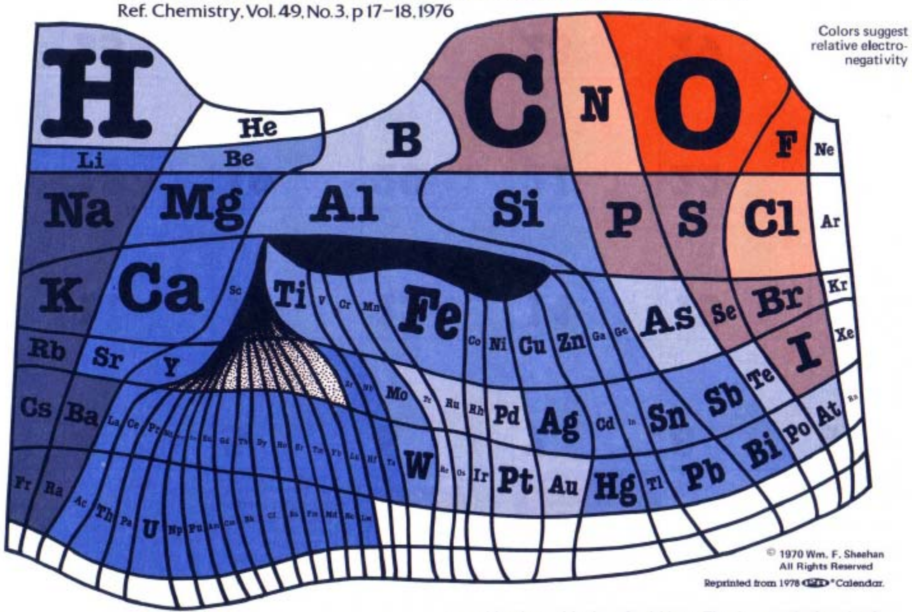
Battery Costs

> “If you want a battery that is dirt cheap, you have to make it out of dirt.”
>
> Donny Sadoway, MIT

Periodic Table

The Elements According to Relative Abundance

A Periodic Chart by Prof. Wm. F. Sheehan, University of Santa Clara, CA 95053
Ref. Chemistry, Vol. 49, No. 3, p 17–18, 1976



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Reprinted from 1978 *Calendar.

Roughly, the size of an element's own niche ("I almost wrote square") is proportioned to its abundance on Earth's surface, and in addition, certain chemical similarities (e.g., Be and Al, or B and Si) are suggested by the positioning of neighbors. The chart emphasizes that in real life a chemist will probably meet O, Si, Al, . . . and that he better do something about it. Periodic tables based upon elemental abundance would, of course, vary from planet to planet. . . **W.F.S.**

The Public Interest

- Promoting innovative storage projects is in the public interest.
- Investment in storage by utilities based on the direct economic benefits will not lead to optimal outlays from a societal perspective.
  - Innovations that do not lead to monetizable intellectual property
  - Spill-over effects that are not captured by the investing utility
- These two important factors militate towards broad-based funding which may include ratepayers or even taxpayers.

Storage – Benefits

- Wholesale Markets
  - energy arbitrage
  - avoided capacity, avoided/deferred investment
  - ancillary services
- Transmission
  - avoided/deferred investments
- Distribution
  - avoided/deferred investments
  - congestion management
  - ancillary services
  - resiliency
- Customers
  - improved reliability
  - backup for critical loads
- Environmental
  - integration of renewables
  - carbon benefit if displacing gas-fired generation
- Electric Vehicle Charging
  - storage critical given high load requirements, especially for rapid charging stations

Cost Allocation – Multi-Product Output

If all outputs are regulated, the allocation problem is manageable, using tools of cooperative game theory. The principles are well-established, though there is no single ‘correct’ allocation:

a. various allocations can be considered fair and reasonable,*
b. mis-allocations can lead to inequitable assignments of costs.

*The ‘core’ of the cost allocation ‘game’ contains a number of plausible ‘solution concepts’.

Cost Allocation – Multi-Product Output

If some outputs are sold in regulated markets, and others are not, the problem becomes more challenging:

a. risks of cross-subsidization of competitive market activities by regulated activities,
b. mis-allocations can result in claims of anti-competitive behaviour, potentially undermining competition.

Battery storage is scalable *and* movable!

If you don’t need it anymore in one location, you can take it somewhere else.

CONCLUDING COMMENTS

Integration of Renewables

- Decentralized resources present major challenges – traditional utilities + DERs.
- Intermittency of renewables requires backup.
- The need for adequate supply has spawned capacity markets.
- Distribution system planning is further complicated by uncertainty about supply, reliability and flexible/responsive demand.
  - Some DERs are substitutes for distribution system enhancements (e.g., storage).
- Electrification of transportation will drive proliferation of charging stations.

Uncertainty and Risk

- Technological change spawns risk and uncertainty. (There is a difference.)

- Who should bear these?
  - utilities and their shareholders
  - other supply side participants
  - energy purchasers (industrial, commercial, residential)
  - taxpayers

- Risk allocation has important implications for investment, technology adoption and innovation, and it therefore represents a critical challenge for instrument design, in the presence of technical change.

Regulatory, Institutional and Legal Issues

Arising out of DERs

- impaired/stranded assets (generation, wires)
- tariff evolution/reform (less emphasis on volumetric?)
- vertical economies of scope (leveling the playing field)
- cost allocation problems (multiple products, regulated vs. unregulated)
- market manipulation and collusion (anti-competitive behaviour)
- regulatory arbitrage (rule design)

Regulatory, Institutional and Legal Issues

Essentiality of *properly balanced* regulatory model.

The need for redesign and evolution of regulatory institutions and supporting legislation. (We tend to worry about market failure, but regulatory failure is also a threat.)

- Under-regulation can result in spectacular failures (think Enron, 2008, Facebook).
- Over-regulation can lead to failures that are more subtle but can have large and far-reaching implications (most importantly stifling innovation and productivity growth, but also unnecessarily increasing costs).

Regulatory, Institutional and Legal Issues

- ‘Integration of renewables’ is part of a larger story about technological change. We do not yet have a good sense of the shape of the next ‘steady state’.
  - What will be the relative roles of macro-grid vs micro-grid vs off-grid; large-scale generation vs. small-scale, distributed generation?

- These uncertainties imply there is much work to be done, in many areas …. regulatory, legal, policy, instrument design, financial, IT, privacy, cyber-security ….
  - New areas of competency for regulatory authorities…

- Different experiments are being conducted in various jurisdictions, from which we can inform our judgments…

- Reliable electricity supply will continue to be paramount.

Thank You!

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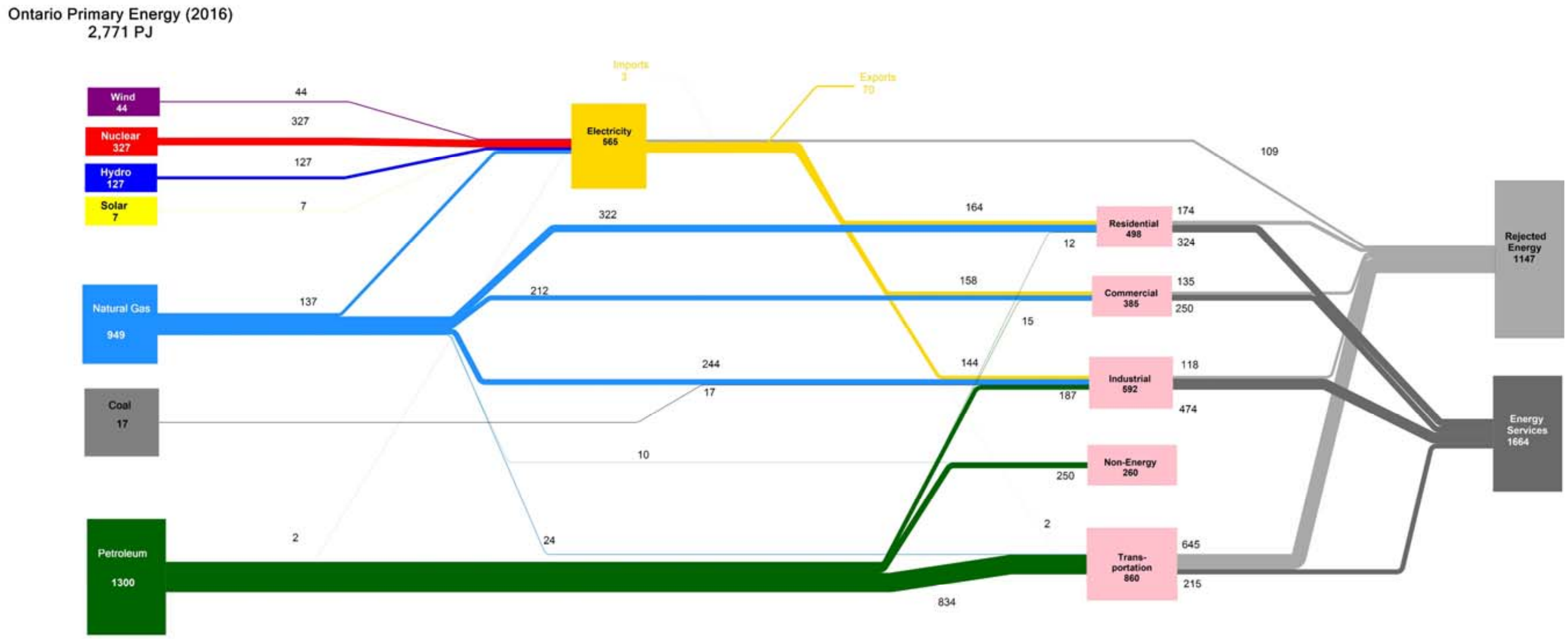
TRANSFERABILITY

Rational vs. Feel-Good Carbon Policy

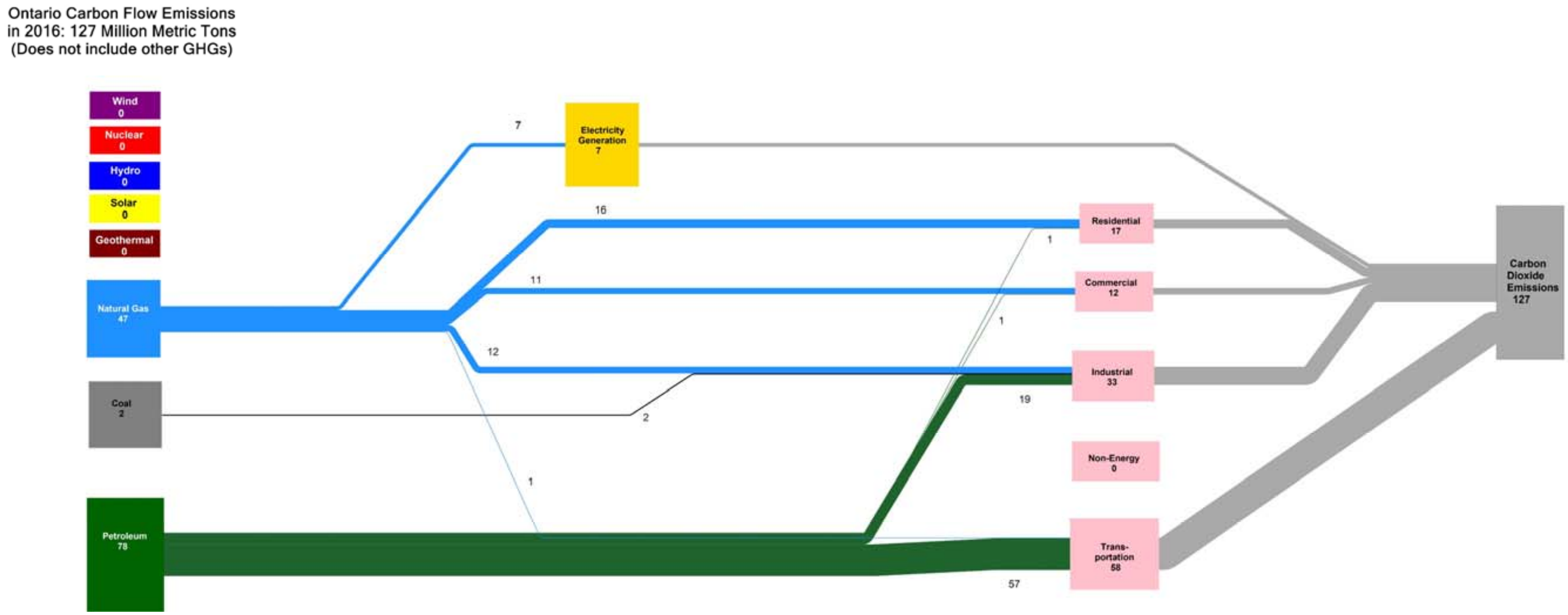
Energy Flow – Ontario 2016



Ontario Primary Energy (2016)
2,771 PJ

Rational vs. Feel-Good Carbon Policy for Ontario

Carbon Flow – Ontario 2016



Transferability

- The most desirable innovations are those that are **transferable** to other jurisdictions.

- Unless China, India and other developing economies can afford the non-carbon technology (solar, wind, storage) we will not solve the global decarbonization problem.