

How the Internet Can Green the Grid

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Joint work with Prof. Catherine Rosenberg, ECE, UW

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otherwise specified



Das Kapital.

Kritik der politischen Oekonomie.

Von

Karl Marx.

Erster Band.

Buch I: Der Produktionsprocess des Kapitals.

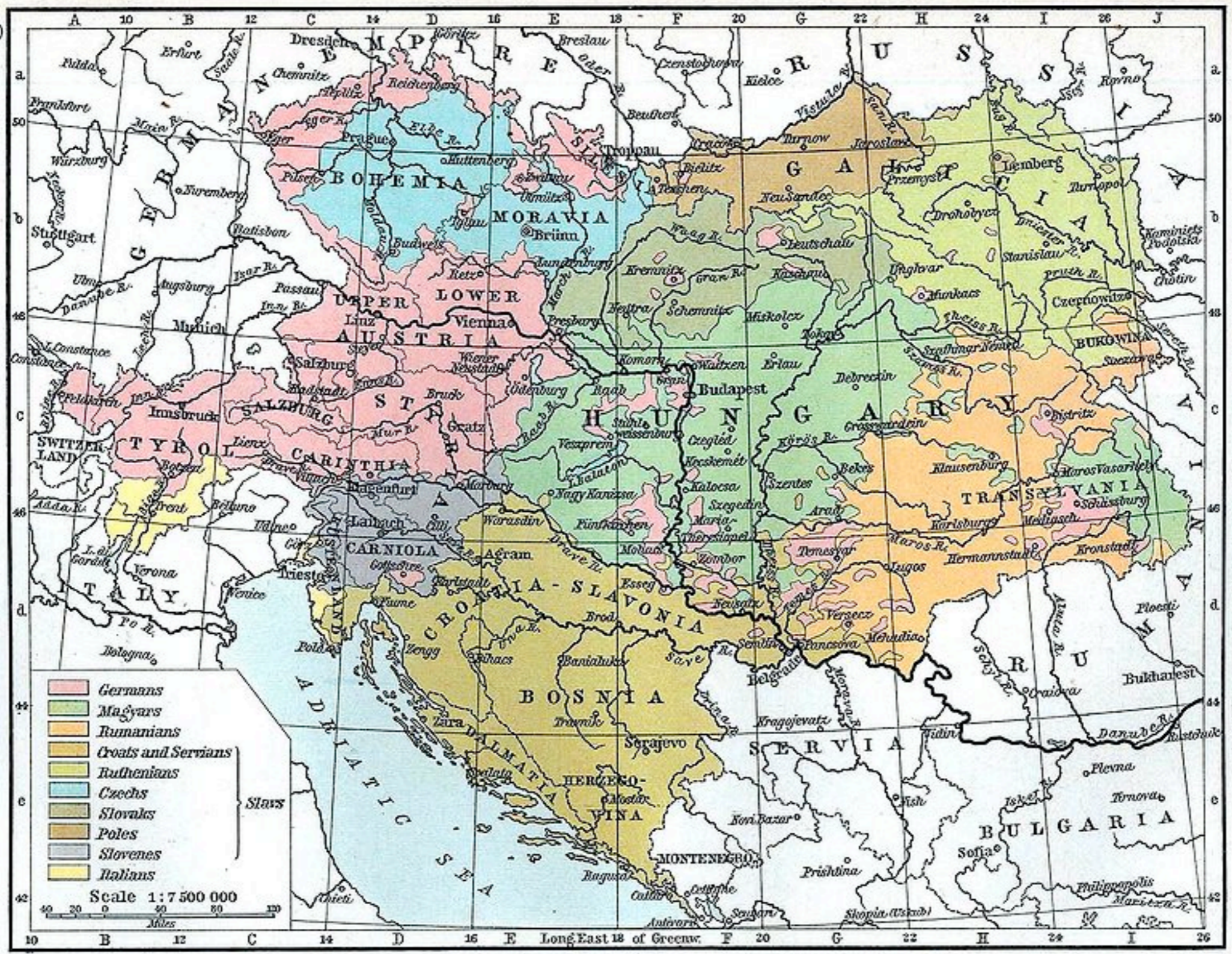
Das Recht der Uebersetzung wird vorbehalten.

Hamburg

Verlag von Otto Meissner.

1867.

New-York: L. W. Schmidt. 24 Barclay-Street.



Distribution of Races in Austria-Hungary.



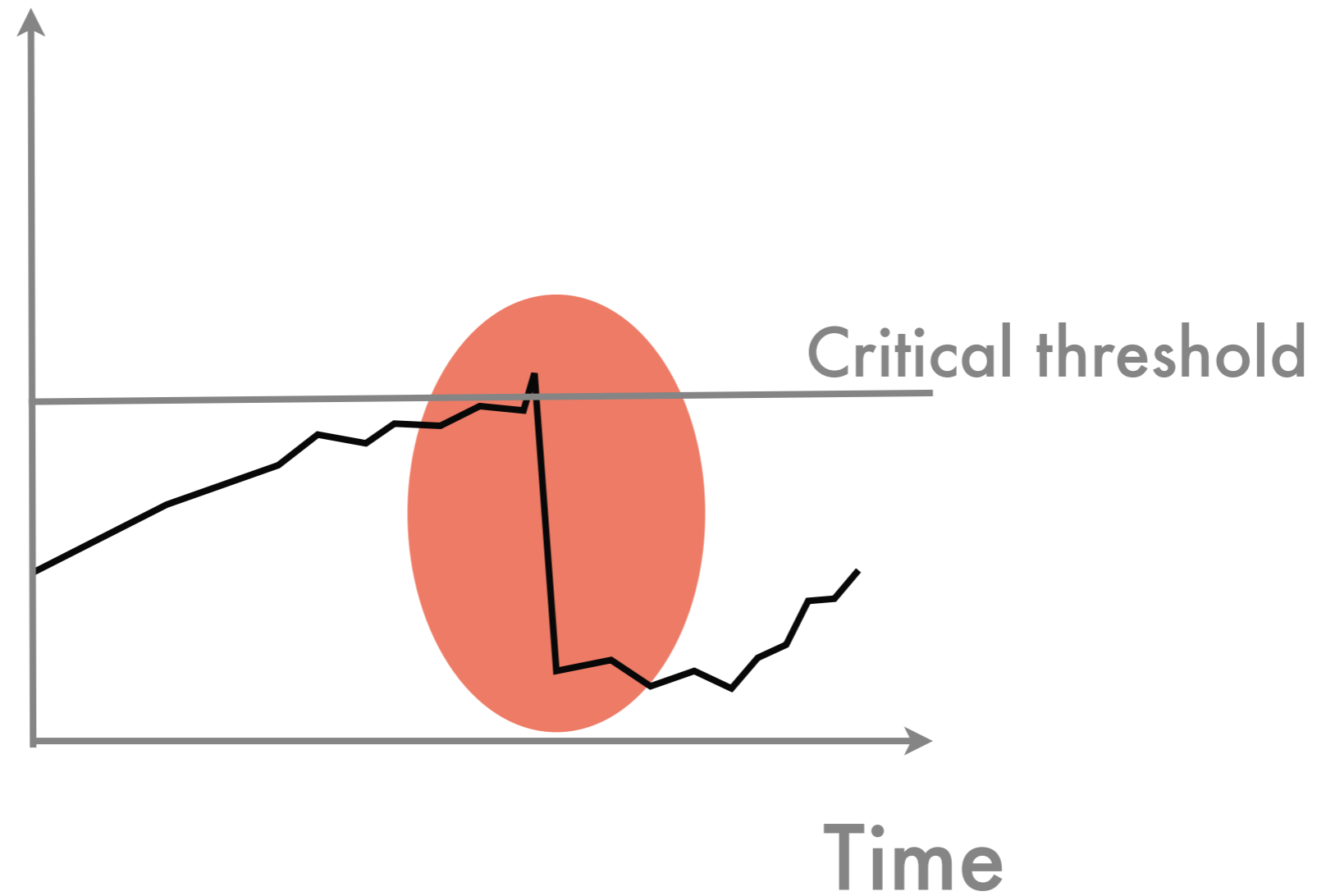






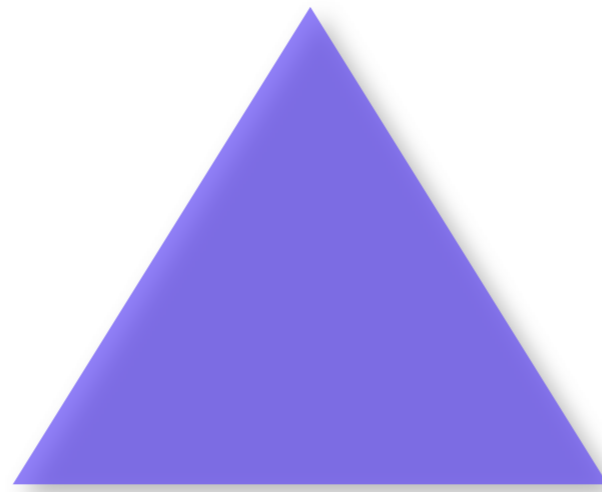


Latent energy



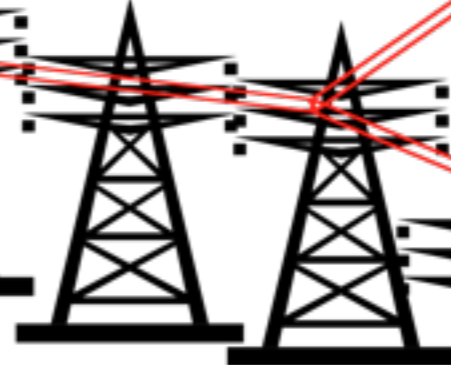
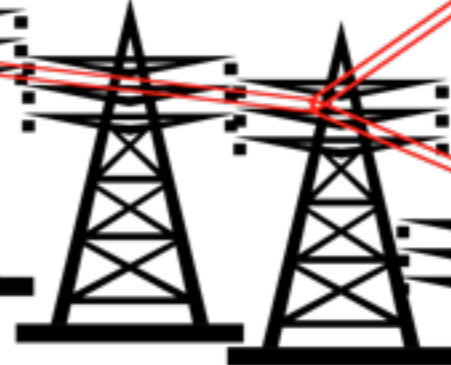
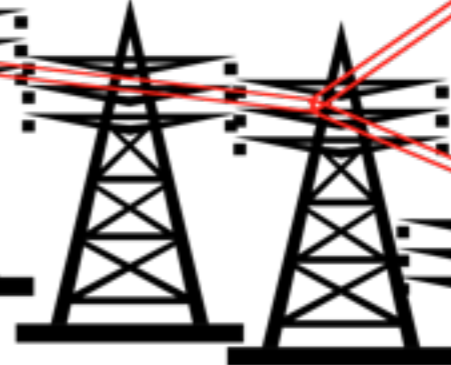
A supercritical system undergoes
abrupt phase change

Internal contradictions



External pressures

Technological push





coal

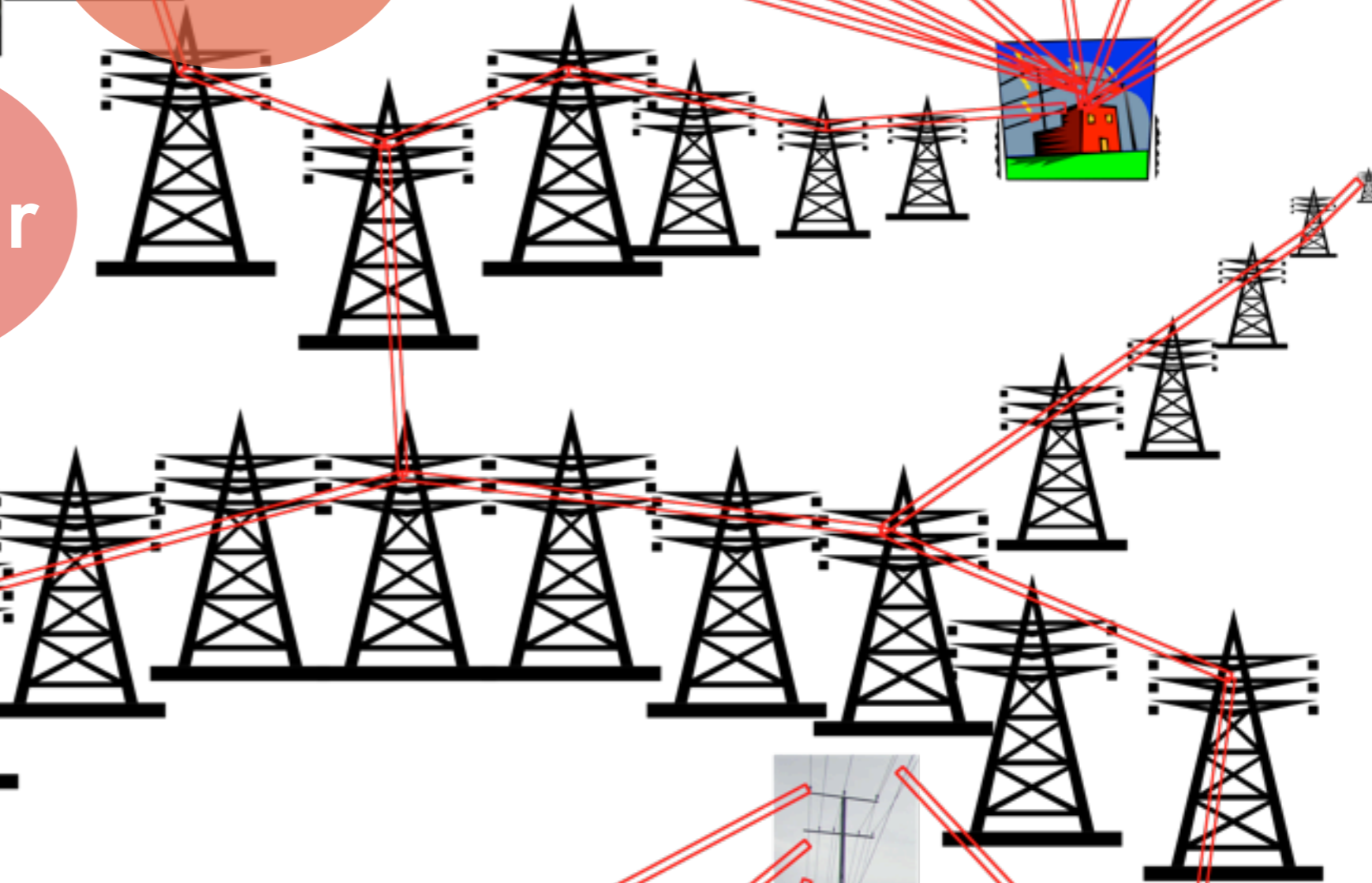




coal



nuclear





coal



nuclear



hydro





coal



nuclear

transmission



hydro





coal



distribution



nuclear



transmission



hydro





coal



distribution



nuclear



transmission

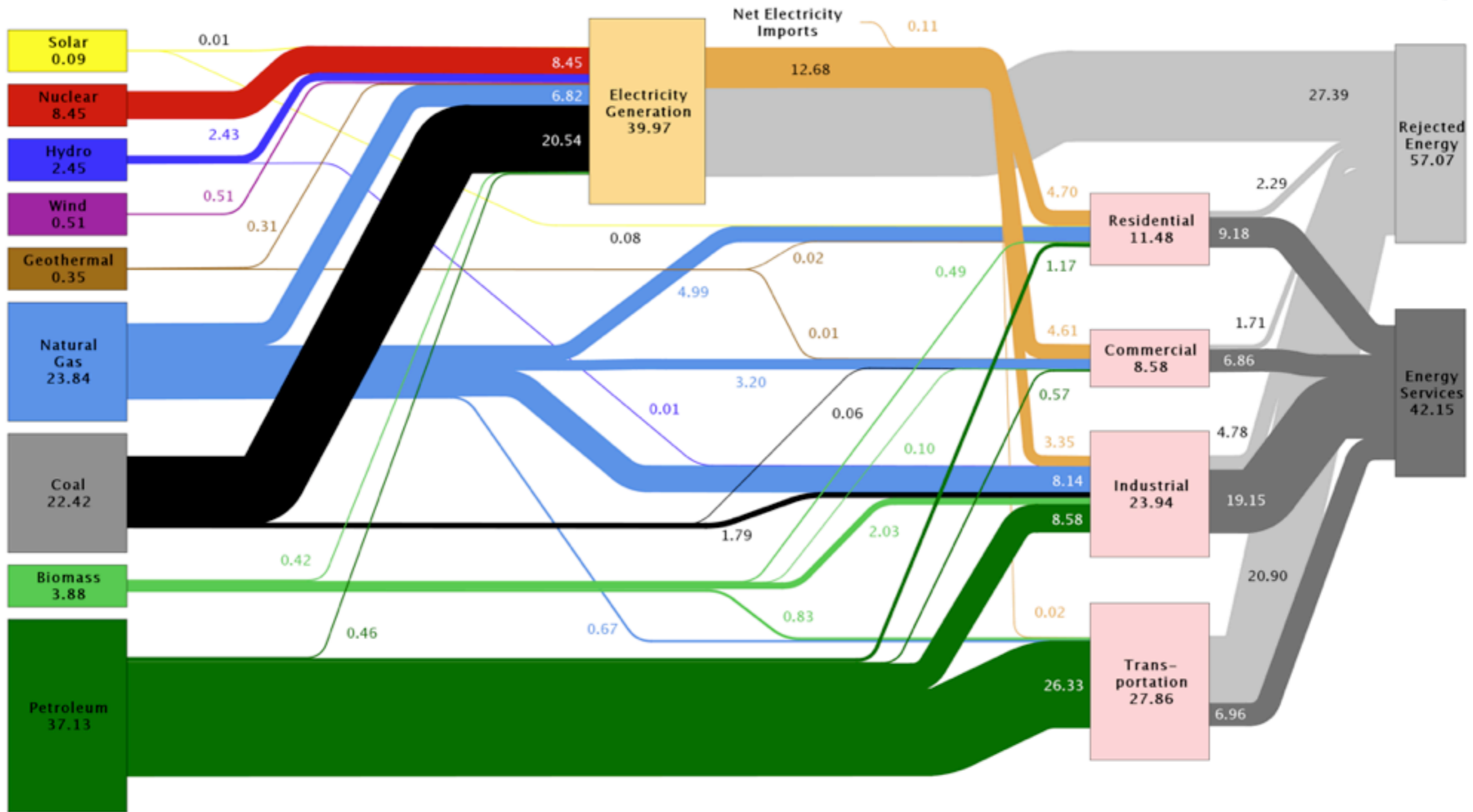


hydro



distribution

Estimated U.S. Energy Use in 2008: ~99.2 Quads



Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

“15% of the generating capacity in Massachusetts is needed fewer than 88 hours per year”

Philip Giudice, Commissioner, Massachusetts Department of Energy, Nov. 30, 2009

Technology ossification



Technology
ossification

Rising energy prices

Technology
ossification





Energy security

Rising energy prices

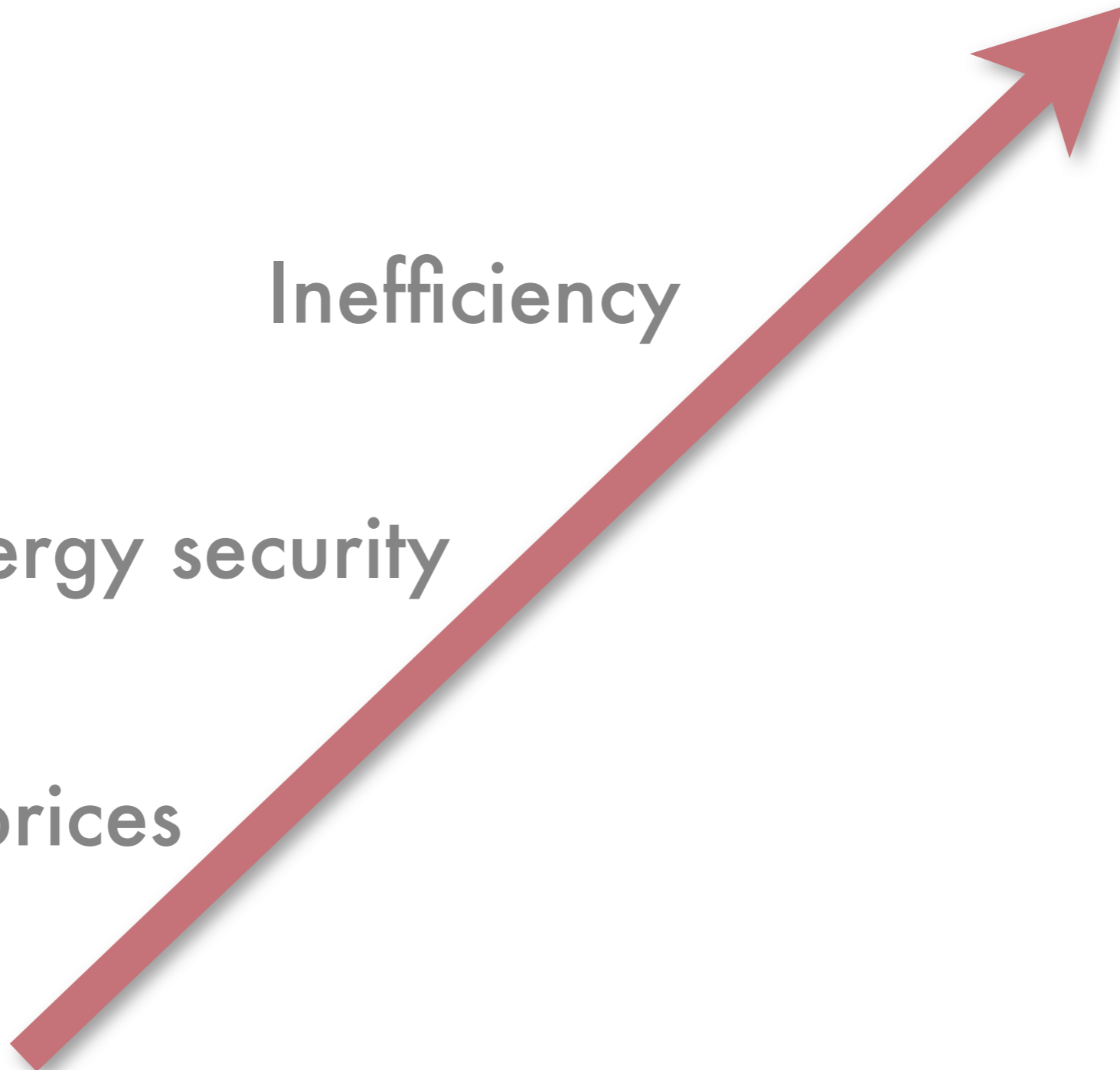
Technology
ossification

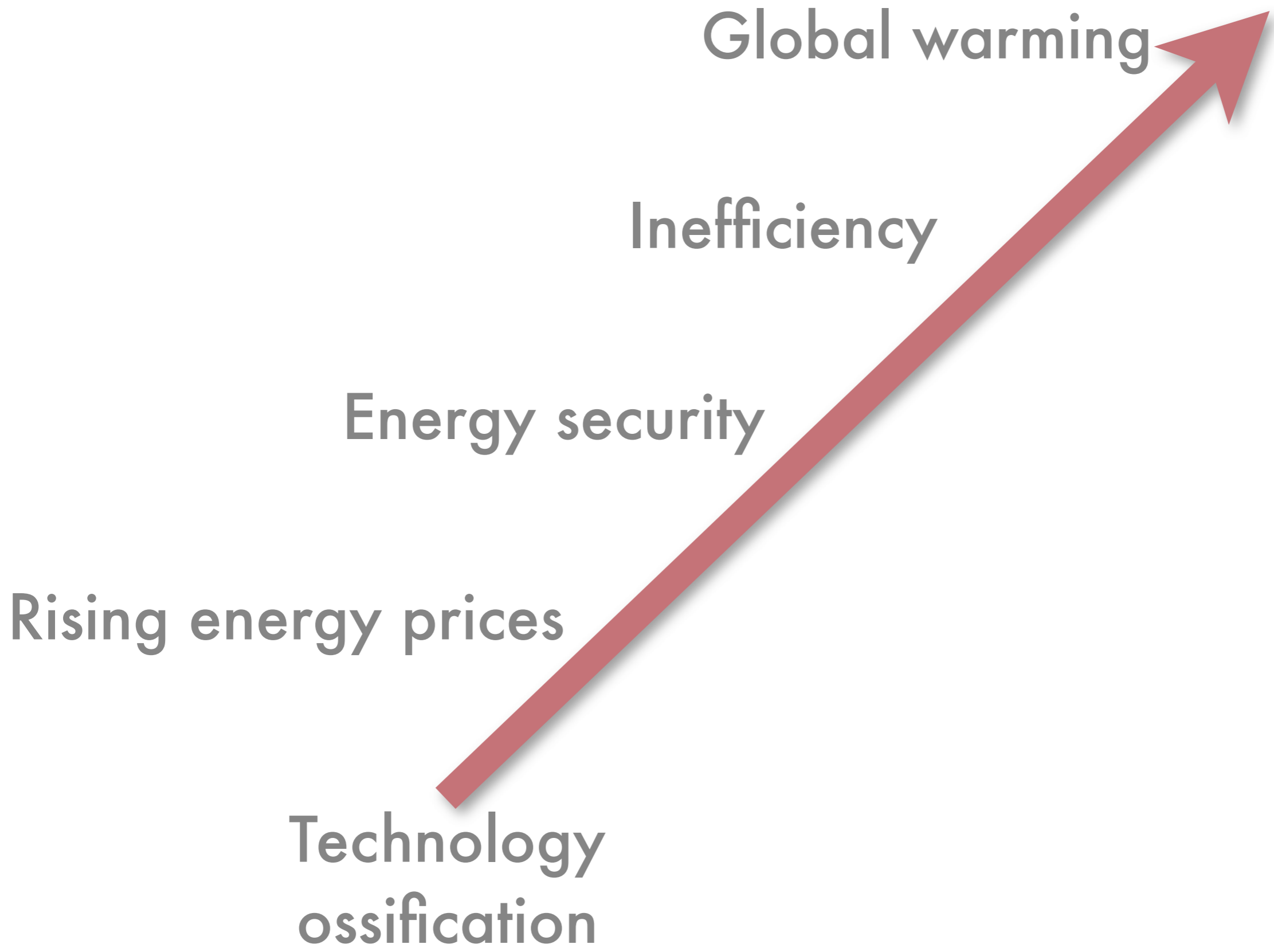
Rising energy prices

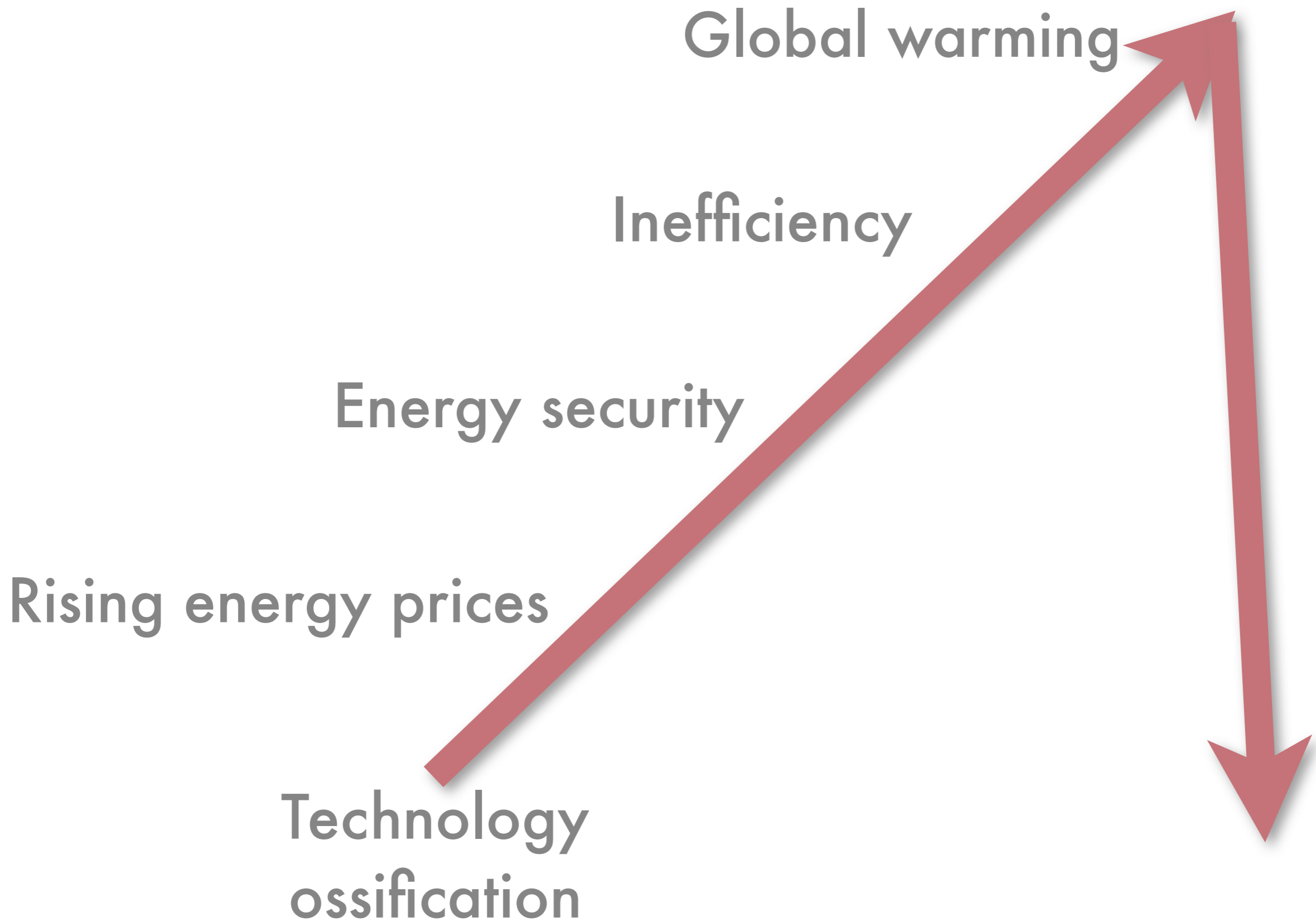
Technology
ossification

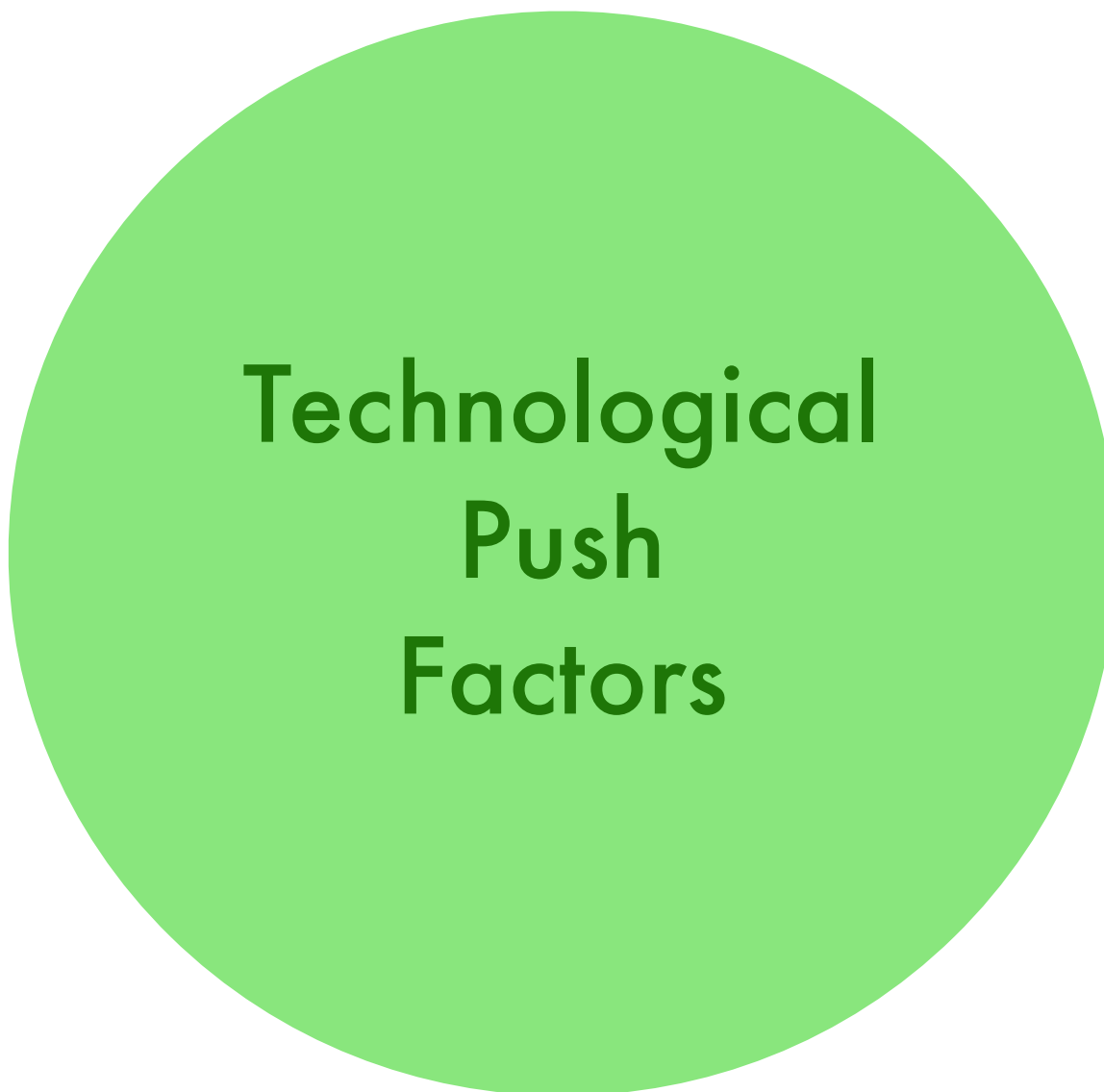
Energy security

Inefficiency



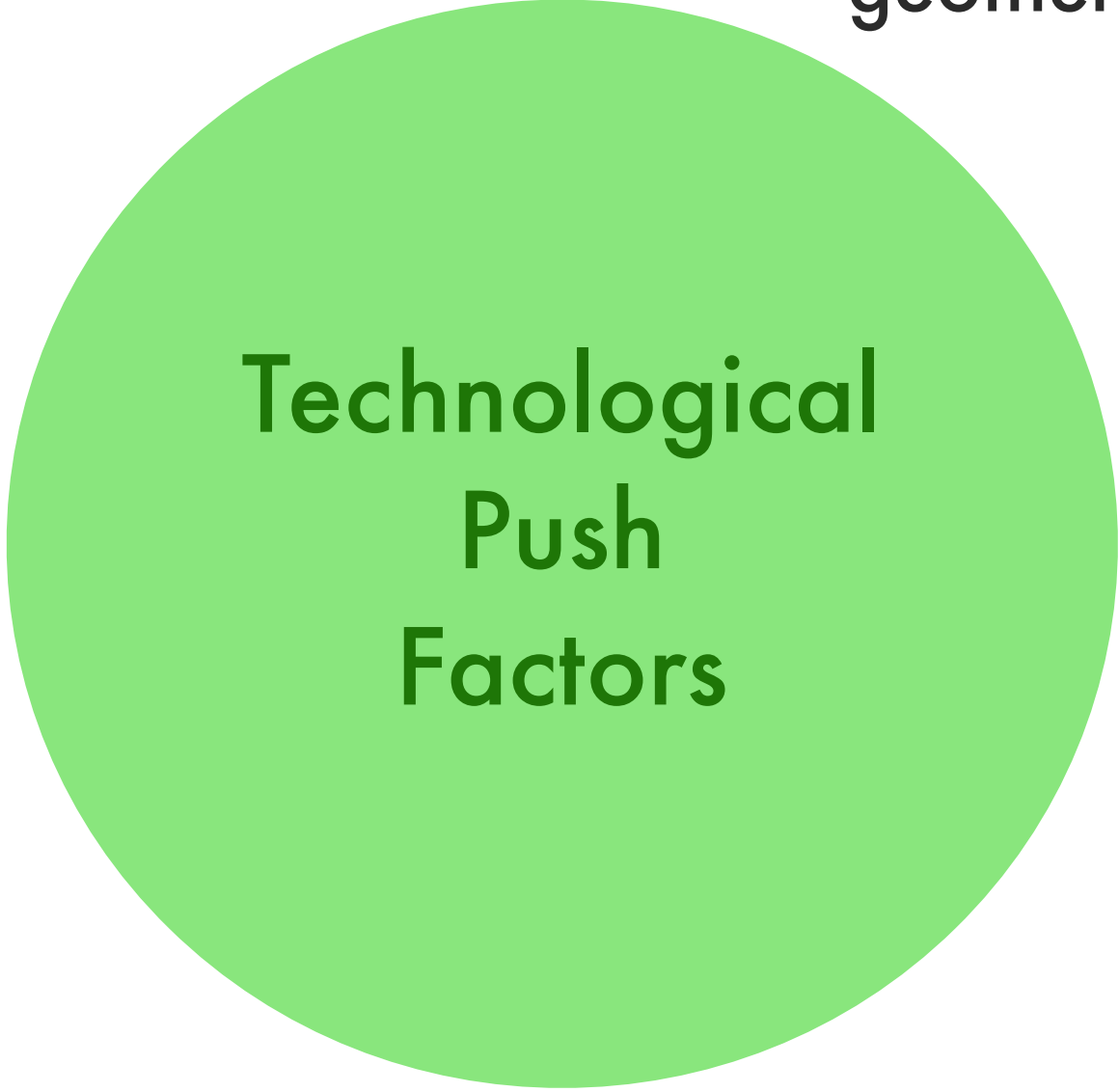






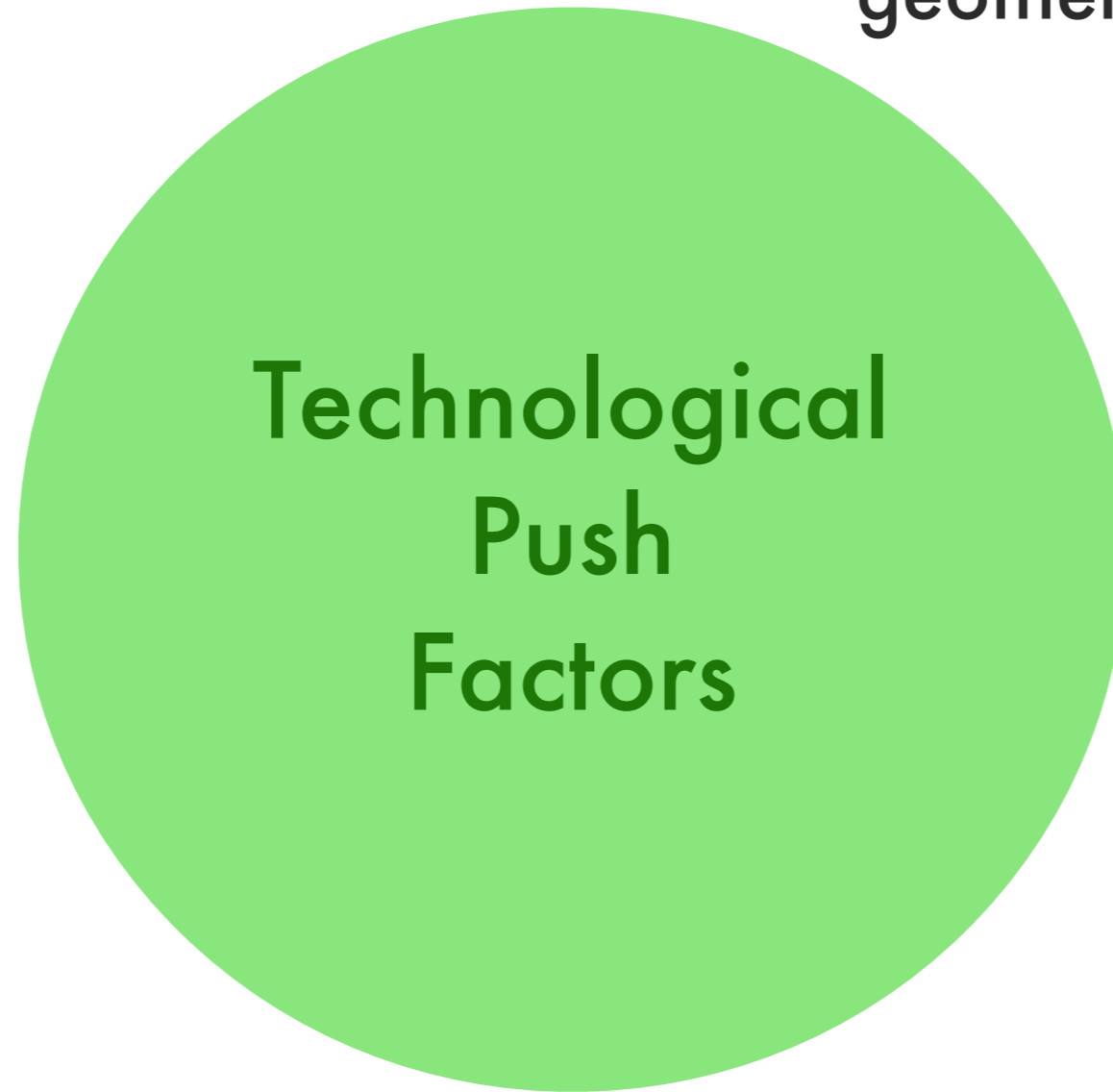
**Technological
Push
Factors**

Solar, wind,
geothermal, tidal....



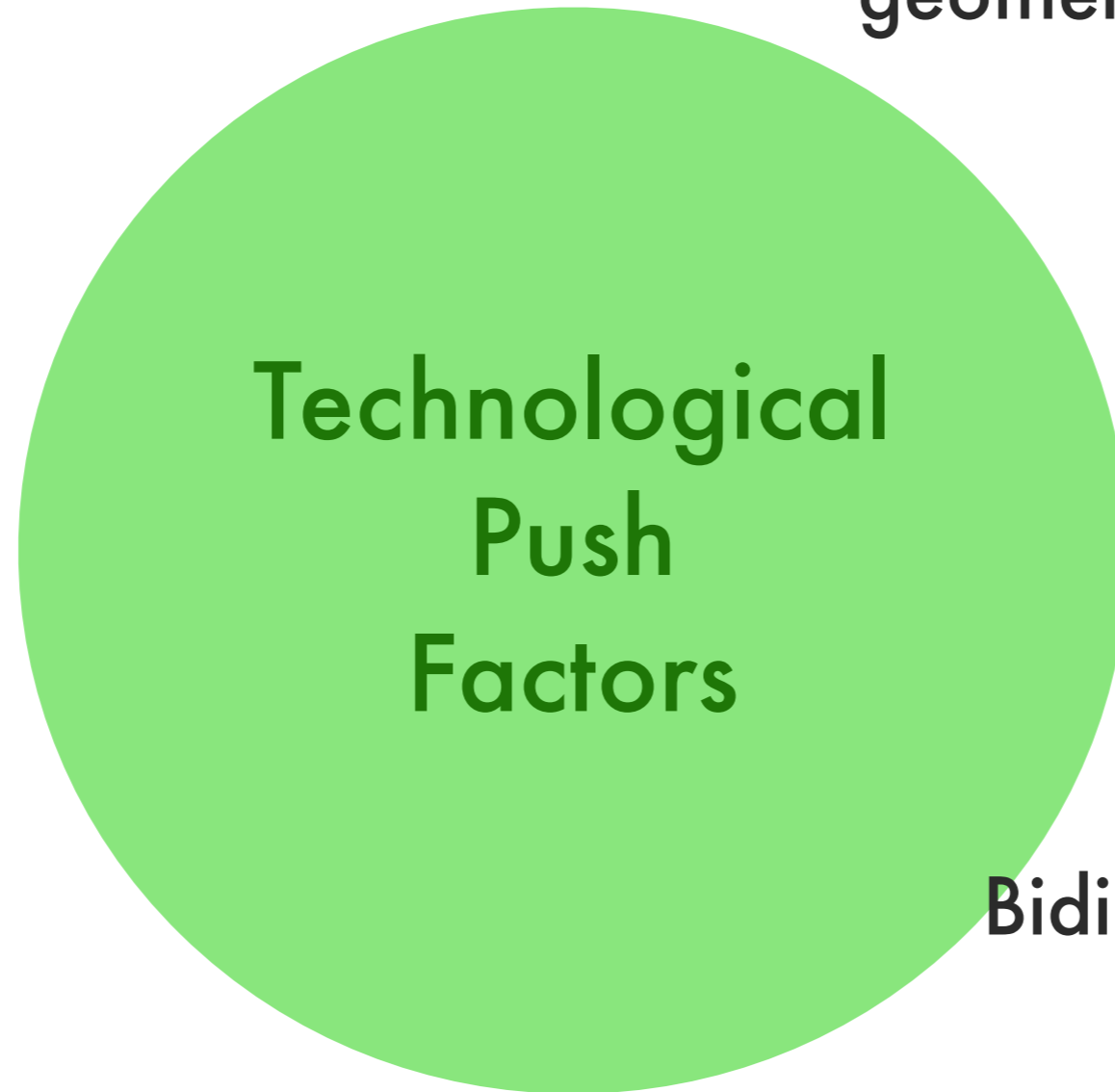
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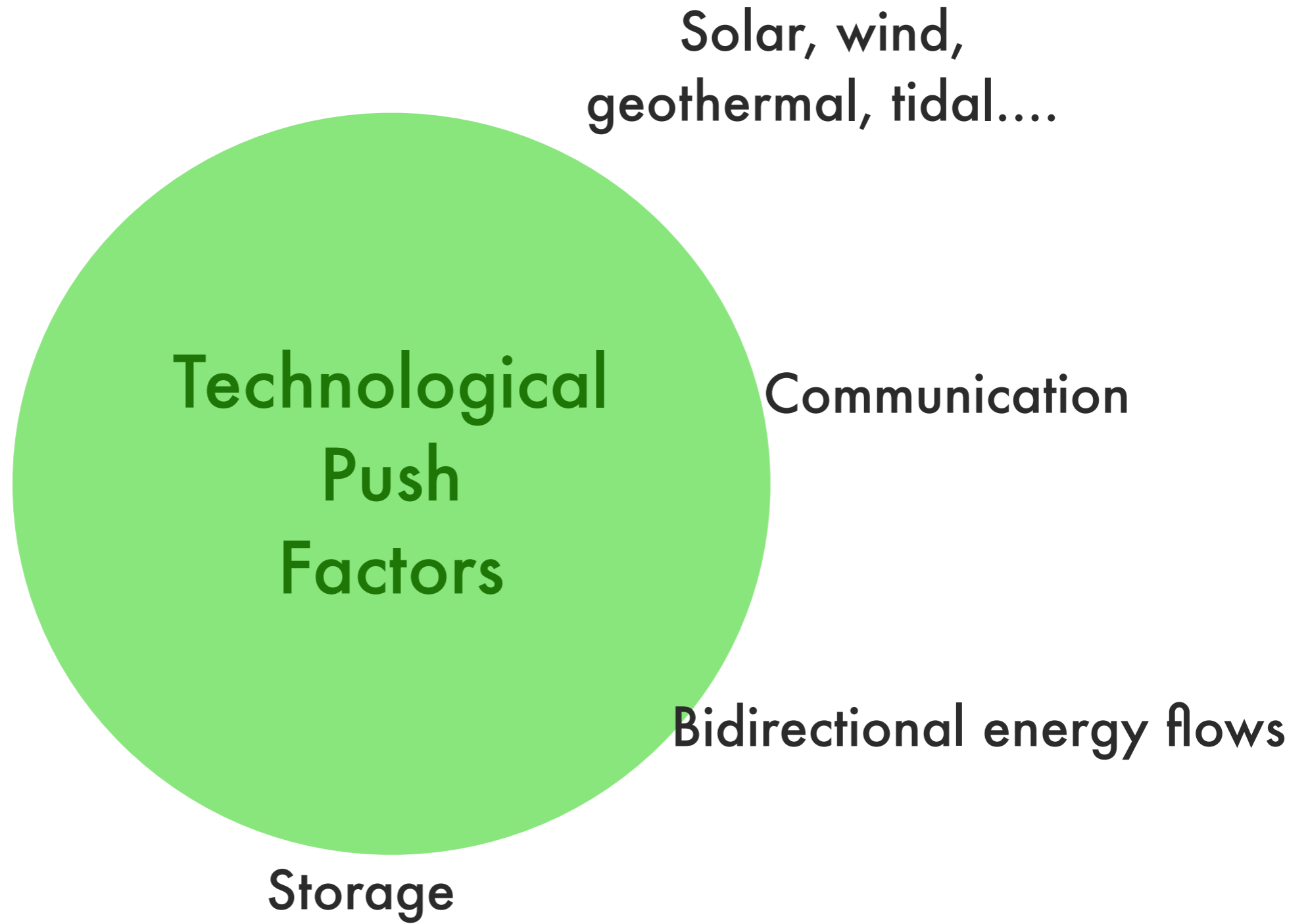
Communication

Solar, wind,
geothermal, tidal....



Communication

Bidirectional energy flows



Solar, wind,
geothermal, tidal....

**Technological
Push
Factors**

Communication

Advanced metering

Bidirectional energy flows

Storage

Solar, wind,
geothermal, tidal....

PHEVs

**Technological
Push
Factors**

Communication

Advanced metering

Bidirectional energy flows

Storage

HVDC and
Superconduction

Solar, wind,
geothermal, tidal....

PHEVs

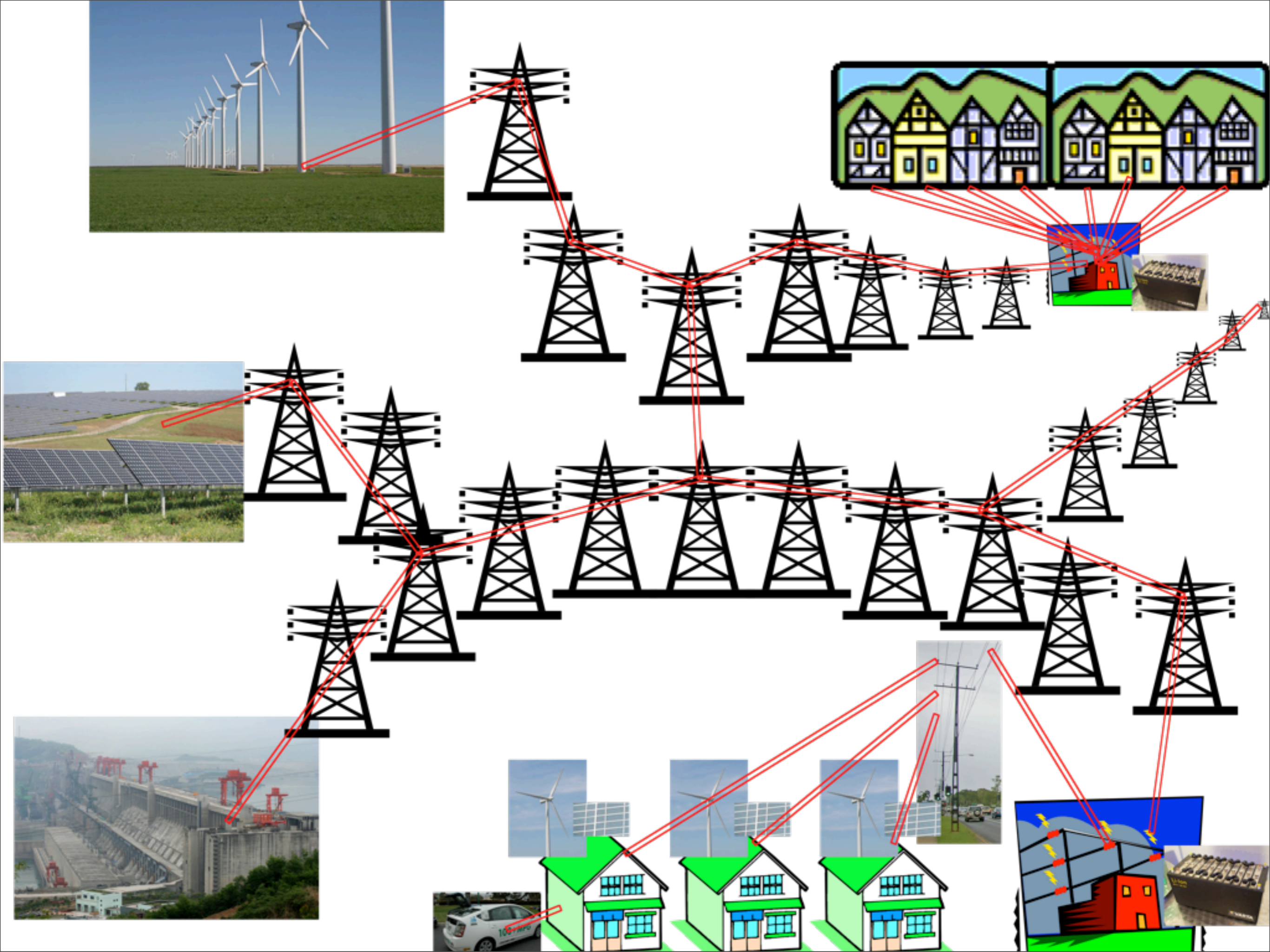
**Technological
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Factors**

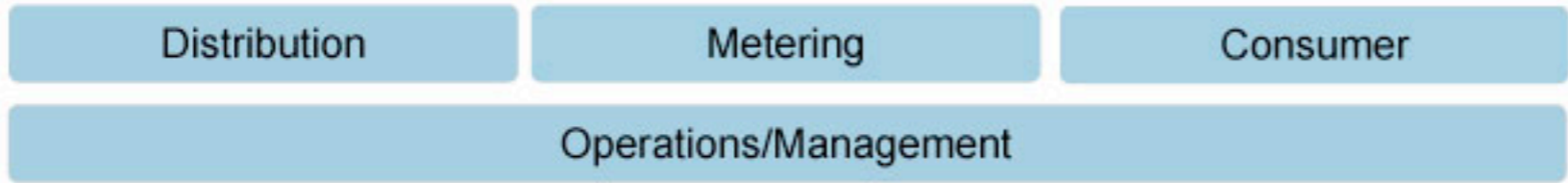
Communication

Advanced metering

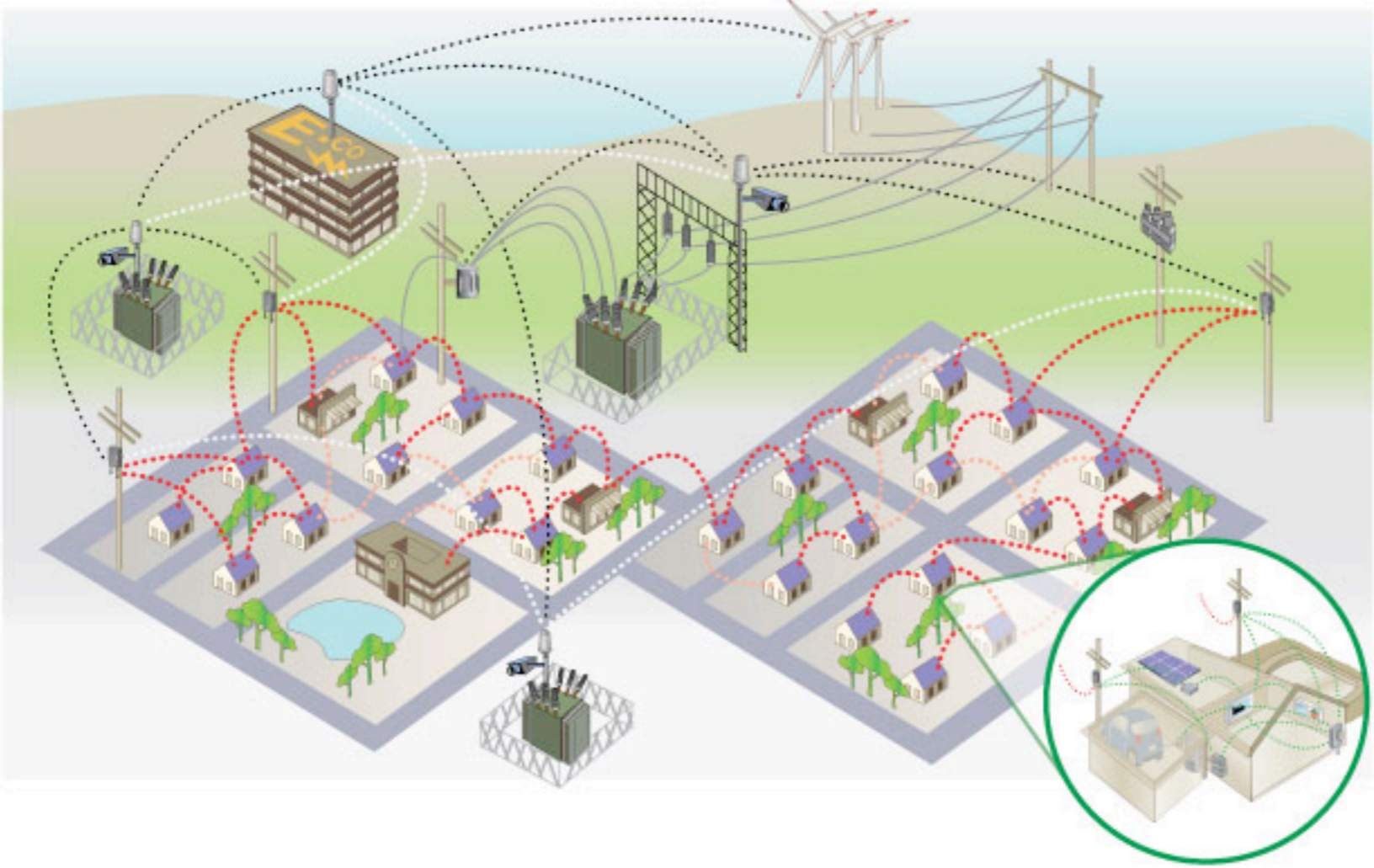
Bidirectional energy flows

Storage





Head-End Software



Distribution
(Wide Area Network)

Metering
(Neighborhood Area Network)

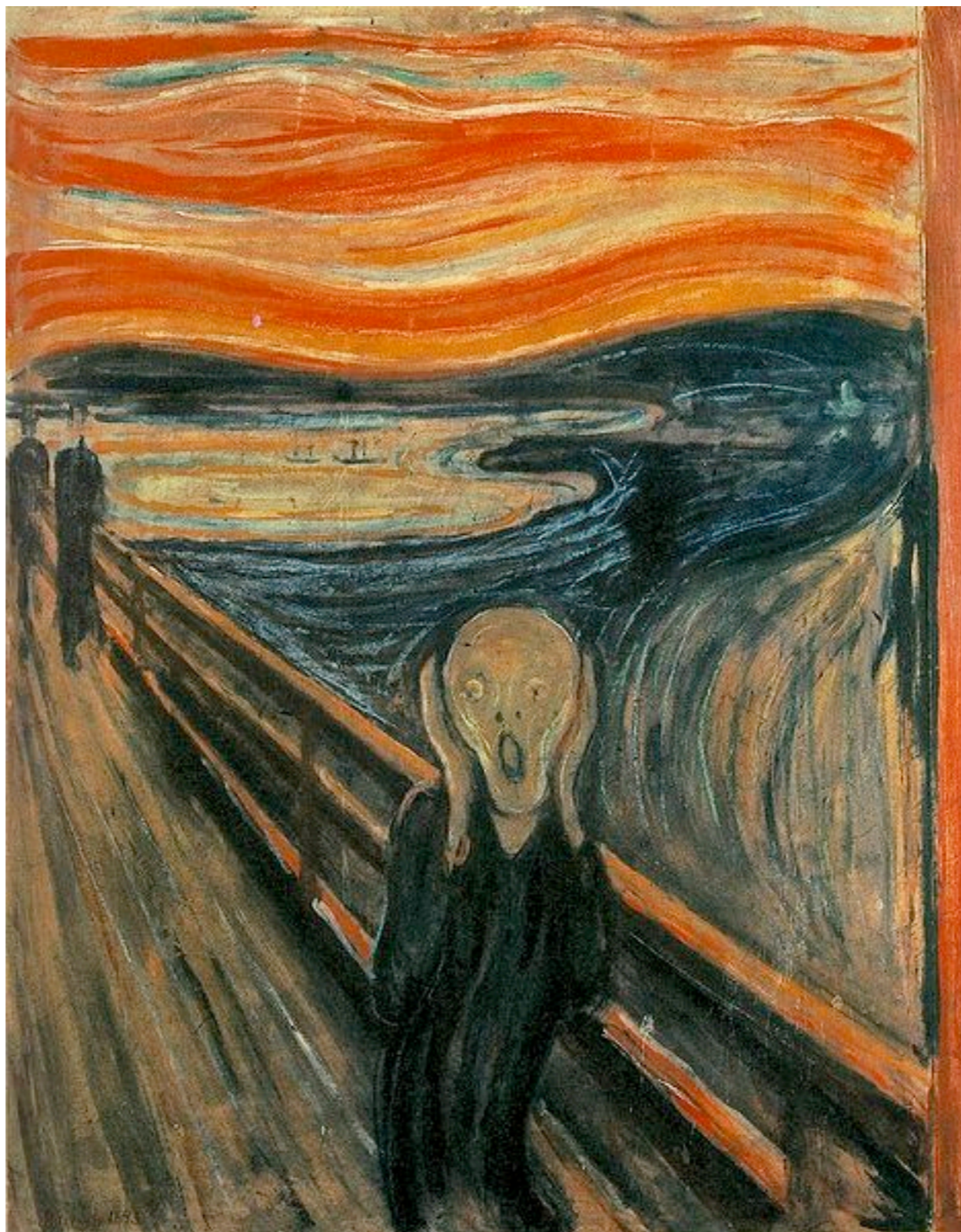
Consumer
(Home Area Network)

Image courtesy Trilliant Corp.

The next decade will determine
the structure of the grid
in **2120**

Problems

- Millions of sources
- Stochastic sources
- Two-way flow
- Non-traditional utility players
- Reliability
- Multiple time scales
- Incentivization
- Security
- Storage
- Variable demand
- Distributed resources



The Internet vs. the Electrical Grid

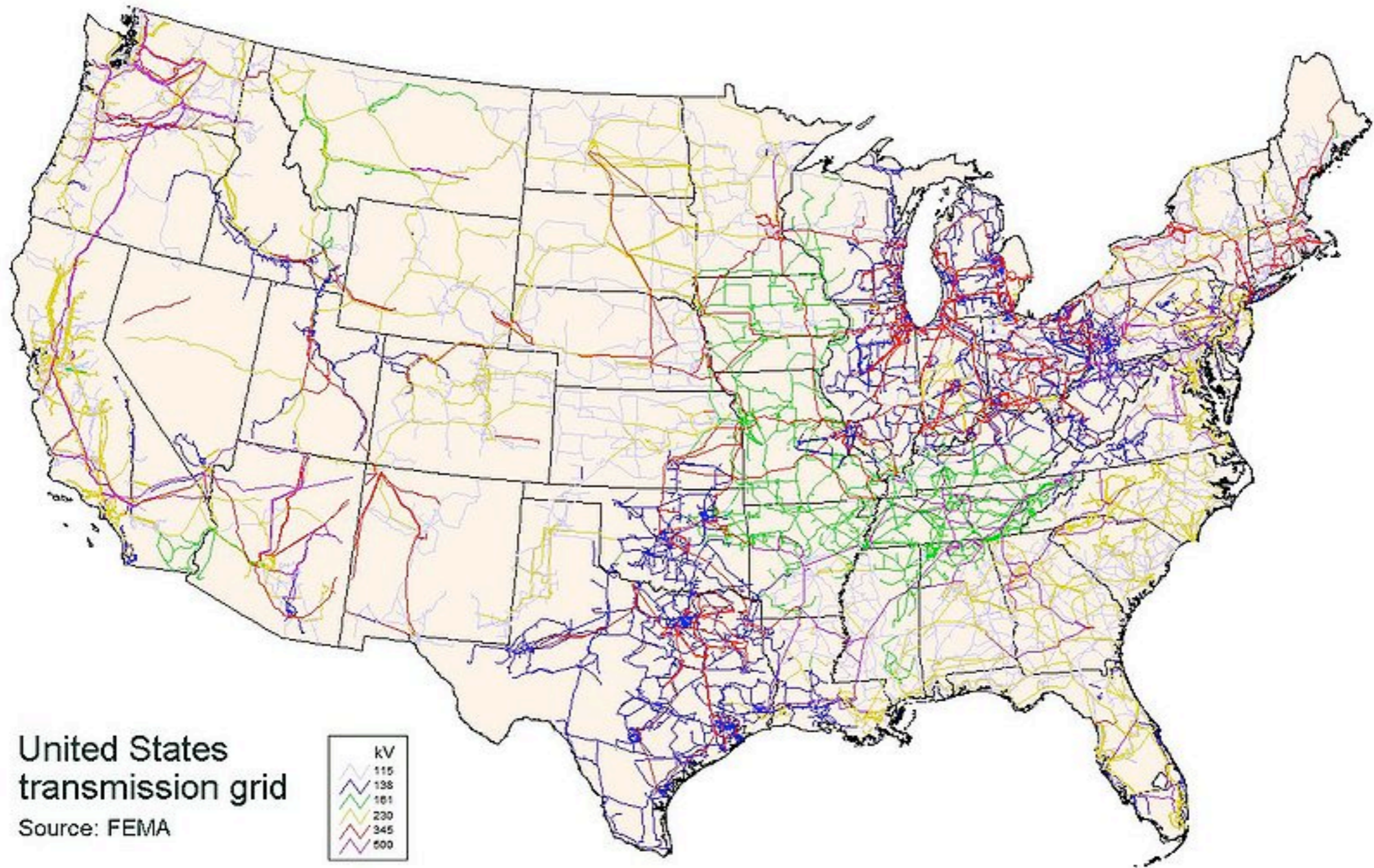
Similarities

- Historically similar
- bottom up + top down
- Vast
- Heterogeneous
- Critical to society
- Ossified



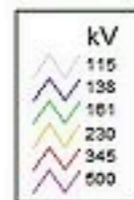
Similarities

- Hierarchical
 - mesh-like core (with special tech.)
 - tree-like access network



United States
transmission grid

Source: FEMA



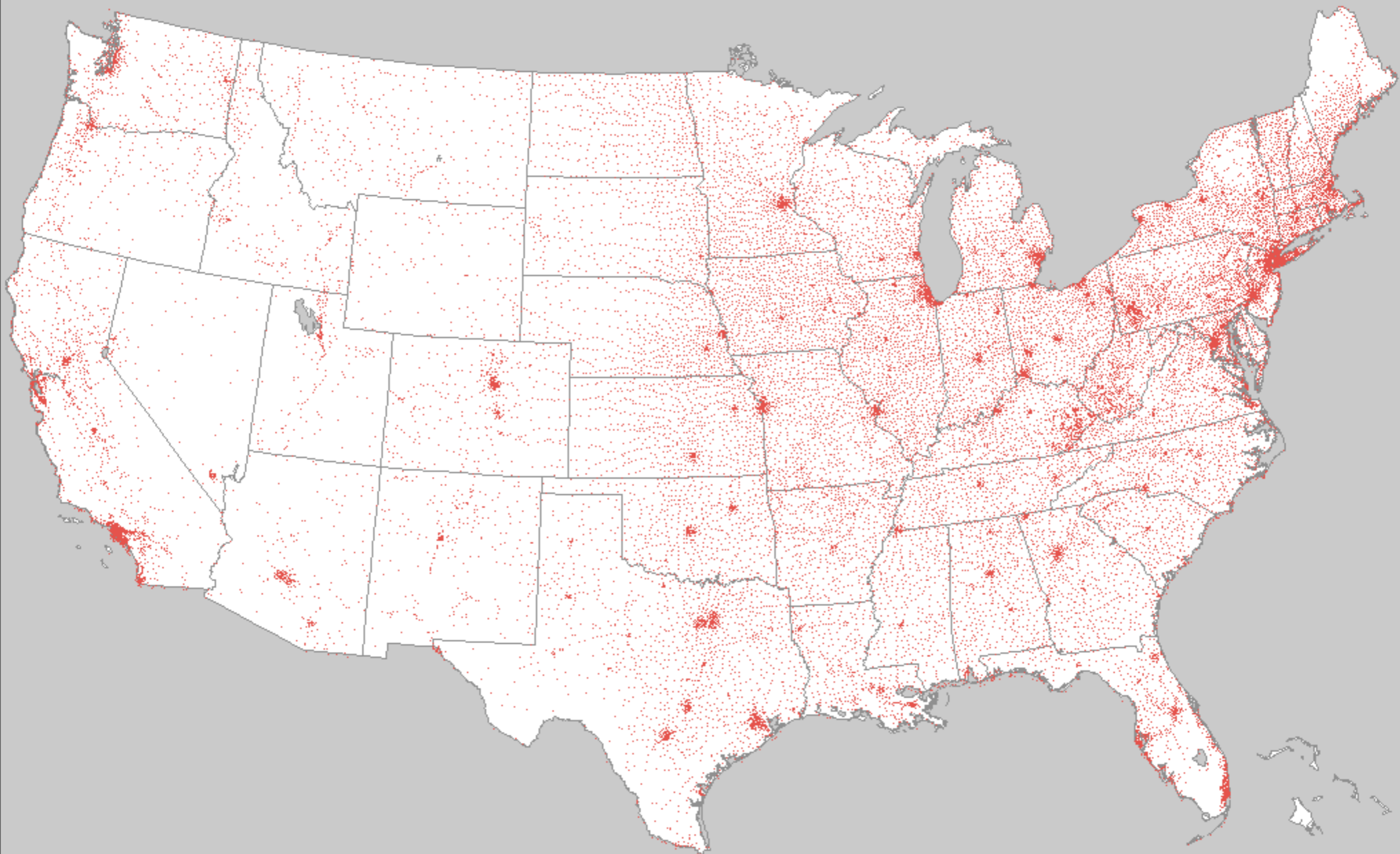


Image courtesy CAIDA

Similarities

- Varying degrees of control
 - Strict at the core
 - Loose at the edges

Similarities

- Storage
- Simple API

Similarities

- Use resource management to match distributed demand to distributed generation

Similarities

- Balance of centralization and decentralization
- Transmission vs. customer care

Differences

- Headers
 - type
 - destination

Differences

- Directionality of flows
 - one-way vs. two-way

Differences

- Time scales of control
 - second vs. hours or days

Differences

- Long-haul transmission
 - fiber optic link vs. towers

Differences

- Predictability
 - flash crowds

The electrical grid is like a
CDN for a single
video stream

Hypothesis

Internet technologies and research developed over the past 40 years can be used to green the grid

Not...

- Reducing electricity use
- Internet as a communication overlay

Local matching

- Transmission loss is isomorphic to delay
- So, use P2P cooperative caching to reduce losses

Tomography

- Determine traffic matrix from monitoring aggregate flows
 - sparse matrix inversion
- Can we determine grid usage similarly?

Stochastic modeling

- {Solar, Wind} == VBR
- Under what conditions is
 $P(\text{Sum} > X) > 0.999999$

DTN

- Delay tolerant networking
 - use 'data mules'
 - they can carry energy too!

Click harvesting

Who will be the Google of the Grid?

Incentive-compatibility

A call to game-theorists



Distributed control

- Blackout == network congestion
- Need to model delays and storage

Simulation

- Continental-scale simulation

CS can help in many ways

Systems

- Understand interaction between many complex sub-systems
-

Databases

- What is the equivalent of separating the layout from the logical view?

HCI

- If a building is a computer, what should its interface look like?

AI

- Decision making for all real systems is under uncertainty!

Conclusions

- 2010-2020 will decide the grid of 2120
- Internet \approx Grid
- 40 years of Internet research {could, should, may} help

<http://blizzard.cs.uwaterloo.ca/iss4e>