Long-term contradiction:

- [1] Economy needs growth
  - Economies of scale
  - Offset diminishing returns
  - Return “profit”

- [2] Growth cannot continue forever in a finite world
Many areas looking at the problem - in silos

My approach: Try to see real story, based on all sources
In a finite world, we find that two types of maps are necessary

- Local maps

- Maps that reflect the finite nature of the world
Economists haven’t discovered need for a second modeling approach near limits

- Supply and demand, away from limits
  - Supply and demand curve
    - $D_1$ and $D_2$

- Near limits, situation is different
  - Energy prices too low compared to cost of production
  - Too few energy suppliers because of low prices
Price problem only appears near limit

- Appears “well-behaved” elsewhere

### Monthly Average Brent Oil Price

Too high for consumers

- Producers started complaining about too low prices

- Prices way too low for producers
Reason why problem is different than expected

- **Producers** and **consumers** of energy products are both important

- Energy prices can be **too high for consumers**

- Energy prices can be **too low for producers**

- Both consumers and producers are important
  - World economy cannot operate without both being satisfied
  - Either **too low** or **too high** a price is a problem
  - Markets affected because producers need profitability
When cost of oil “E&P” suddenly rises, but wages don’t, prices behave strangely

Figure by Steve Kopits of Westwood Douglas. CAGR is compound annual growth rate.
Current oil price level appears to represent lack of *affordability*

- Result is low prices; glut of oil

- “Supply – demand” terminology is confusing
  - Should be “supply – amount affordable”
Economic situation is like mirror image problem - more complex than expected

How the Economy Grows

and

What Goes Wrong
Tools are clearly one key to economic growth

- **Tools broadly defined**
  - Machines
  - Roads
  - Vehicles
  - Computers

- **Rising quantity of tools** leads to growing productivity
  - Tools act to leverage human labor

- Growing tool use leads to more energy consumption
  - Both to make and operate tools
Making these tools also requires _debt_.

- Problem with tools: _benefit is all in the future_.

- Need to create tools using human labor, plus energy and mineral resources, _before_ the benefit is received.
  - How can the economy pay for these tools?
  - Debt and debt-like instruments
  - Selling shares of stock acts like debt as well

- Using debt, it is possible to **pay workers now, for the future benefit that tools will provide**.

- Need for debt, besides energy, when tools are added is _part of mirror image problem_.

*Important!*
An economy produces goods and services

Growing quantity of energy products and other resources

Growing number of workers

Growing supply of ever-improving “tools”

= Growing quantity of goods and services produced
How should the output be divided? Adding debt *provides enough to pay everyone*.

Future Goods and Services

Growing quantity of goods and services produced

Includes Interest

 Owners of
Growing quantity of energy products and other resources

Owners of
Growing number of workers

Owners of
Growing supply of ever-improving “tools”
Reducing the debt level becomes a huge problem - tends to **drop prices too low**

- A *decrease* in debt (or too small an increase) shrinks wages and prices

Amount available to repay *current* workers and owners

Amount of goods and services actually produced
Another source of insight: studies of past collapses

- See what happened when (resources/population) fell too low

- Similar to less arable land per person
  - Able to work around with more technology, such as irrigation

- Avoid standard false reasoning
A few insights from historical collapses
(Turchin and Nefedov; also Joseph Tainter)

- Slowing growth and greater use of “complexity” preceded collapses

- Greater complexity involved specialization; more tools and technology
  - Problem 1: Rising complexity leads to increasing wage disparity
    - Some get specialized training; others do not
  - Problem 2: Complexity reaches diminishing returns (Tainter)

- Ultimately, collapse comes because **wages of non-elite workers fall too low**
  - Non-elite workers can’t afford output of economy
  - Governments can’t collect enough taxes
  - Epidemics may become a problem, because of poorer nutrition
Shape of cycle based on Turchin and Nefedov analysis

Using fossil fuels, we seem to be following same pattern:

Tverberg image based on Turchin and Nefedov analysis in *Secular Cycles*. 
In US, income disparity grew after 1980; inflation adjusted income flat since 1998

**Real Household Income at Selected Percentiles: 1967 to 2014**

Source: US Census Bureau
How adding tools/technology eventually leads to collapse

1. Energy extraction reaches diminishing returns, because we extract the cheapest-to-extract first.
2. Benefits of new technology reach diminishing returns.
3. Debt tends to grow rapidly—leads to wealth concentration and interest payments to the wealthy.
4. Specialization leads to wage disparity.
5. Non-elite workers become too poor to afford output of economy.
7. Energy producers leave market because prices are too low.
8. Tax collections fall, eventually leading to governmental collapse, or over-run by a stronger economy.
Economy is a self-organized system that grows in the presence of energy and debt

- Energy part of system is reaching *diminishing returns*

Physics: Our *economy* is a *dissipative structure*

- Dissipative structures self-organize and “grow” when flows of energy are available. Examples:
  - Hurricanes
  - Stars, including the sun
  - Ecosystems
  - Plants and animals

- Each type of dissipative structure is a little different

- Energy flows are *essential* to the operation of dissipative structures

- All dissipative systems are temporary
  - Grow and eventually collapse
My view of economy as a dissipative structure

- Acts much like a rocket, thanks to “Other Energy”
Peak oil story seems to be a mirror image of the correct story

- Peak oil is not a “new and different” problem
  - It is a repeat of (resources/population) falling too low

- Result is likely falling prices, not high prices
  - Wages of non-elite workers fall too low
  - Cannot afford the goods being produced

- Easy to build model using false beliefs of economists
Elephants in the Room
1. Wind and solar can’t really save us

- Everyone has modeled the problem in the wrong way

- Issue is not “How much electricity can a solar panel or wind turbine produce?"
  - And how much fossil fuel will this displace?

- Issue is how wind and solar will affect the overall system
  - Extent to which they artificially lower wholesale electricity prices
  - Extent to which they drive electricity producers needed for backup from the marketplace
EROEI of a solar panel is not EROEI of the overall system

- Solar Panels, With Smart Inverters to Cut Off Peaks
- Price System Doesn't Work for Any Fuel; Every Electricity Producer Needs Subsidy!
- Need Winter Capacity; Pay Other Producers To Sit Idle Most of Year
- Need Rapid Ramping Capacity; Add Batteries, Hydro Pumped Storage, Pay NG Producers
- Add More Transmission To Smooth Out Peaks And Valleys
- New Transmission Makes Buying From Neighbors Optimal

Today’s EROEI Calculations End Here.
EROEI tells us essentially nothing about cost of wind and solar - but cost seems to be high
No one models how the system really works, because problem is too complex to model!

- Solar Panels, With Smart Inverters to Cut Off Peaks
- Price System Doesn’t Work for Any Fuel; Every Electricity Producer Needs Subsidy!
- Need Winter Capacity; Pay Other Producers To Sit Idle Most of Year
- Add Rapid Ramping Capacity; Add Batteries, Hydro Pumped Storage, Pay NG Producers
- New Transmission Makes Buying From Neighbors Optimal
- Add Transmission To Smooth Out Peaks And Valleys

All of Today’s Calculations End Here
All analyses equivalently false

- EROEI
- Levelized cost of electricity
- Low auction prices of wind, solar
- New IEA report
- Energy payback period
- Life cycle analysis

All look at one piece of problem
But not the important pieces!
Issue in all reports is over-focus on problems away from limits; under-focus on true issues

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  - Too few energy suppliers because of low prices
2. Our economy has no option but to grow. If it shrinks, it collapses.

- Issues are hollow nature of system; role of debt

Economy must grow, requiring ever-more energy

- **Problem 1**
  - Can’t go backward to less energy-intensive uses
  - Example: Can’t go back to the use of horses instead of cars

- **Problem 2**
  - Need to keep adding new debt, and repay existing debt with interest
  - Debt underlies financial system
  - Financial system will collapse if we try to shrink
    - Will have worse problems than 2008
3. Growth of world economy requires a growing quantity of ever-cheaper energy

- Falling energy prices enable growth of rest of economy

Chart by Roger Fouquet
UN world data also shows falling energy expenditures as GDP% (bottom two layers)

- Economy rebalances to the *cheapest fuels*
- Prices can fall below the cost of production

![Figure 2. World GDP sector added value shares](image)
Attempt to shift from cheap coal to high-cost renewables is futile

- Can’t produce enough renewables, cheaply enough
4. International organizations of governments, such as the EU, are at risk

- Expect these signs when an economy has energy surpluses:
  - Rapidly growing economies
  - Rapidly growing tax revenue
  - Energy products (oil, coal, natural gas, renewables) provide considerable tax revenue
  - Worker productivity rises
  - Wages of workers, even non-elite workers, rise

- Recent problems are signs of too little surplus energy

- Most vulnerable organizations are top level organizations
  - Soviet Union collapsed in 1991, when oil prices were low
5. Oil exporters can expect to have problems similar to Arab Spring uprisings

- Issue is continued low oil prices – budgets require $100+ oil

- Oil exporters cannot afford to maintain programs for their citizens, without high taxes made possible by high prices
  - Food subsidies
  - Fuel subsidies
  - Programs to provide jobs, schools, hospitals

- Large unemployed population is likely to be angry

- Example: Venezuela
  - Ironic that the country has the world’s largest “proven oil reserves”
    - Problem: Proven reserves are of no value unless oil price is higher
  - In danger of becoming a “failed state”
6. Low oil prices may lead to lower oil production and falling productivity

- Low oil prices lead to inadequate investment in new oil fields
  - Production too low by 2020, according to IEA
  - Also, exporters may start failing for financial reasons

- With less oil, total energy use falls
  - Less able to build new, more efficient “tools”
  - May use existing “tools” less
  - Less leveraging of human labor
  - Falling productivity more of problem than today

- Temporary spiking of oil prices doesn’t really help
  - Business will add labor, rather than more “tools”
  - Addition of more oil requires long-term high prices
How We Arrived Where We Are Today
1. We have been expecting too much of models of **pieces of the system**

- EROEI is a specialized tool that measures tips of icebergs.
- Doesn’t produce consistent readings for renewables and fossil fuels.
2. Other issues also contributed

- Too much wishful thinking

- Addition of limits adds a whole different dynamic
  - Virtually everyone missed the *low price* problem
  - Similar to world as a sphere, instead of a flat plane

- Research approaches don’t get quickly to the right result
  - Peer-review system perpetuates wrong thinking
  - Financial grants involve analyses of small pieces of the system
  - Have to see for ourselves that new approaches don’t work!