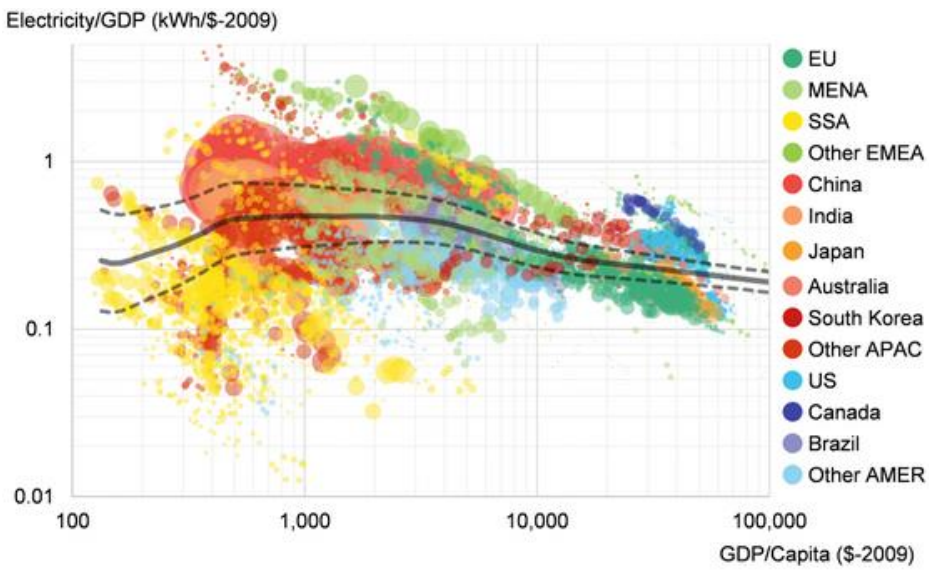
Chapter Eight - The alternative energy matrix

It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so.
~ Mark Twain

The watercolor chart below compares economic growth to electricity efficiency. Each color represents a country or region. "As economies get richer, growth requires less power" states the publisher. It is true there is good news in this, we are learning to do more with less, as we so desperately need to, but the statement also white washes or overlooks a number of important truths…about 1/3rd of the world's population doesn't have electricity today, and it is fair to say, for most, they to want it. Second, as we have covered before, electricity, is the minority of the globes energy requirement, ultimately thermal output from fossil fuels is about 80% of our demand. Finally, with the huge amount of manufacturing that left the G7 and went to Asia to say the G7 is becoming more energy efficient is pretty much bunk. Real solutions need to understand and address fully, such realities. Figures don't lie but liars sure figure.

The Beauty of Efficiency



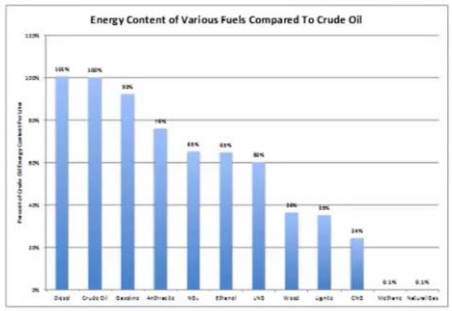
Source: BNEF

In 2016 about 26 per cent of Germany's **power** supply came from renewable sources.

Not All Energy Is Equal

	Net Energy
Oil (Saudi Arabia)	100:1
Coal	50:1
Hydroelectric	30:1
Oil (Global Average)	30:1
Wind	18:1
Wave	15:1
Natural Gas	10:1
Nuclear	10:1
Geothermal	8:1
Solar PV	7:1
Oil Sands	6:1
Shale Gas & Tight Oil	5:1
Biofuels	3:1
Solar Thermal	2:1

Source: Heinberg and Barnatt



Source: EIA

- Net energy from shale gas and tight oil is less than from solar PV.
- Net energy content of natural gas liquids is <65% of crude oil or gasoline.
- Net energy content of natural gas is <1% of crude oil or gasoline on a volume basis and only 24% as CNG and 60% as LNG.

Labyrinth Consulting Services, Inc. artberman.com Slide 10

ARC Financial summed up a lot with the following: “The facts show that fossil fuels have fought off many market share challenges to their supremacy over the past several centuries. I can think all the way back to King Edward I who banned the burning of coal in 13th century England…So here we are, over 700 years later, and we’re still burning the black stuff and choking on it in places like China. My point to the challengers of the status quo is that the established players don’t roll over and cede market share without a full-on market share battle that pulls out all of the stops on fighting back”. Truth is, to the degree they have found there is limited need for “fighting back”. Back in 2008, Google announced an ambitious plan called “Clean Energy 2030,” which called for weaning the United States off oil and gas for electricity generation by 2030, and reducing oil use for cars by 44 per cent. A few years later, Google gave up and pronounced the plan undoable but that does not stop an ongoing full court press to push the same policies on the peasants.

“There is no shortage of information – and misinformation – about energy use, renewable and the need to curtail (or eliminate) the use of hydrocarbons, because of their non-renewable nature, there are many economic and practical realities about renewable forms of energy that are often not considered or simply ignored. We believe these realities will cause the transition to renewable to take much longer and cost significantly more than might be realized (by most people)”... says John Mawdsley, AltaCorp Capital in his report Renewables VS Hydrocarbons – The Energy Reality, which we reference quite a bit below because in our view it was so well done and has held up very well to the test of time.

The issues to be addressed regarding energy use, and the necessary conversion to renewable, are vast, extremely challenging and very complex. While it is true and urgent that society needs to reduce consumption on hydrocarbons, it is also true that we have huge new demands for energy emerging regularly such as internet servers for the internet of things, bitcoin, robotics, and even cannabis grown under artificial lights, at the same time, as it is also true that developing economies want, and require, an ever-increasing amount of energy. These two truths are fundamentally in conflict.

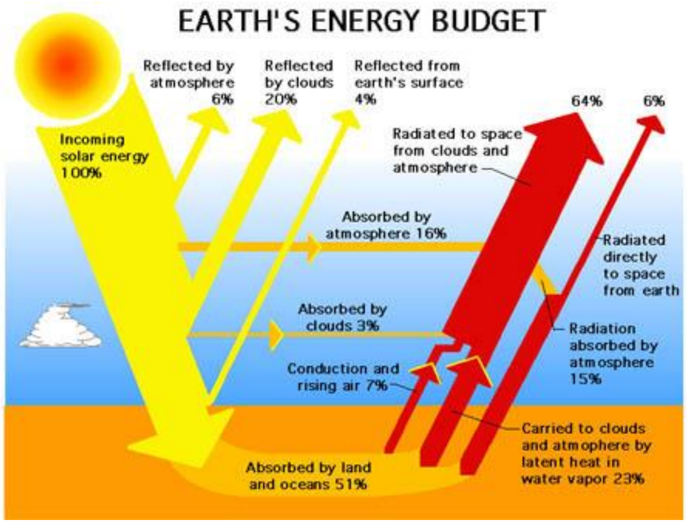
To put in context how difficult the transition to renewable will be...To replace just the coal-fired electricity in the United States, it would take solar panels valued at approximately $4.4 trillion (many times larger than the 2008 US financial crisis bailout package). The limiting factor, moreover, is the current inability to store the power generated during sunny periods for use throughout darkness and times of cloud cover. There is no current technology to store this amount of electricity on a practical basis. To put the significance of the storage problem in context, it would take approximately nine billion car batteries (those used in automobiles for starting the engine) costing about $950 billion to store the solar power. The nine billion batteries represent over 34 times the number of batteries in the roughly 260 million registered vehicles in the U.S.”

California had embarked on a massive project that mandated 1.3 gigawatts of solar storage by 2020. And storage on a smaller scale is proceeding. In early February 2015, entrepreneur Elon Musk announced that his latest project is mass production of 10-kilowatt-hour home-battery packs—designed by Tesla and manufactured at a giant “gigafactory” in Nevada—that will power a house for two full days without sun. 500 homes outfitted with these batteries are already proving up the tech in California. Musk expected them to go commercial in about six months… It’s 2022 and how has the hype stacked up to the reality?

https://www.zerohedge.com/geopolitical/bolivian-coup-comes-less-week-after-morales-stopped-lithium-deal

“The Leduc reservoir, which is a very important to the province as it produced millions of barrels of oil, that reservoir contains hydrocarbons but on a volume basis it probably contains about 95 per cent brine. There’s billions of litres cubed of that brine water in the sub-surface, it is enriched in lithium.” See https://www.sherwoodparknews.com/news/local-news/lucrative-lithium-potential-looms-in-alberta for more details

https://www.zerohedge.com/news/2019-06-23/inconvenient-truth-electric-cars



Environmental Realities of Energy

“Environmental impacts need to be considered for all forms of energy use including renewables. All too often, it is an overall simplification of one source of energy being “bad” and another being “good”. For instance, the amount of water used in biofuels is significant; biodiesel crops use over 500 times the amount of water than an oil sands mining project for the same amount of energy produced. Hydroelectricity also has large impacts, based on the amount of carbon-absorbing forest or precious arable land that is lost when yet another valley is flooded (fish habitat lost, etc.).

A simple example is electric cars, many of which are coming to market with claims of being emissions-free. However, this claim does not take into account where the electricity came from in the first place. Assuming that electric cars are distributed widely throughout the United States, 51.2% of these cars will actually run on coal. It is a stretch to claim “electric cars are leading a green revolution,” when half of them would currently be powered by coal, the most emissions intensive hydrocarbon. This is a commonly repeated mistake, where a small subset of the world’s multifaceted and complex energy issues are examined in isolation. The answer may be accurate, when a subset of energy issues is viewed, but in terms of addressing the world’s energy challenges it may have limited value (at best) or be misleading (at worst)”.

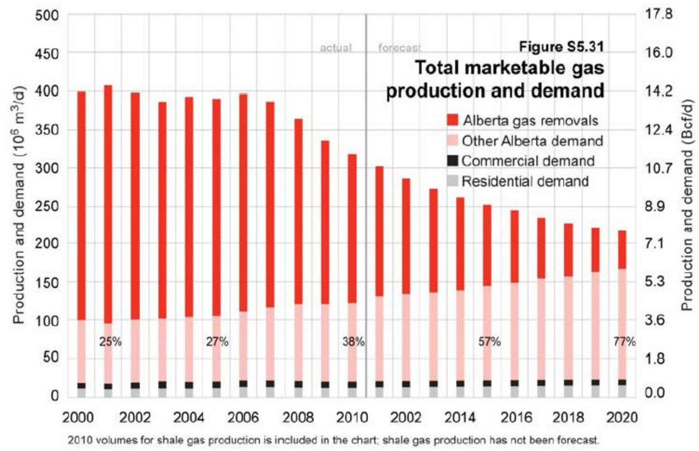
Meeting Growing Demand

“If global energy demand was to increase by only 1.2% per year, total consumption would grow by almost 60% over current levels by 2050. This increase represents approximately three times the current total energy use, from all forms. The ability of mankind to extract this amount of energy from the earth over the next 40 years will be a monumental – if not impossible – task; a challenge made more difficult by trying to do so with fewer greenhouse gas (GHG) emissions and using more renewables. Perhaps all energy sources having an ability to grow but global economies have been struggling mightily to grow despite current low energy costs, growing populations and historically low interest rates. Energy and population has a large say as to why.

It is said there is a powerful group that have determined that the solution is eugenics or the termination of a large amount of the population. Of course, this notion is so grossly offensive let alone any claim it is being acted on means the discussion of it is highly supressed. We find that understandable and we will leave the matter there.

***“It is our view that mankind needs to reduce its energy needs by choice, or the choice will be forced upon us”* John Mawdsley, AltaCorp Capital Inc.**

Tragedy of the Hydrocarbons "Mankind has a preference for hydrocarbons, because of their convenience and low cost, but there is a tragedy developing related to our ongoing use of these non-renewable resources. We call this The Tragedy of the Hydrocarbons, which is related to Garrett Hardin‟s The Tragedy of the Commons. In the Tragedy of the Hydrocarbons, individuals will choose to consume hydrocarbons because they are the most economic form of energy available and the most convenient. Because of their non-renewable nature, our ongoing use of hydrocarbons is slowly "emptying the tank." Even huge natural gas resources now being exploited with new drilling, fracking and completion techniques will run out...



Source: ERCB Report

The tragedy lies in the reality that people will continue to use and deplete the non-renewable hydrocarbons, even though it is not in the best long-term interest of the individual, society, mankind or the planet for this to continue. Relying on a non-renewable resource will eventually force us to reduce consumption and use renewable forms of energy, but the transition will (in the Tragedy of the Hydrocarbons context) likely be difficult and painful. Even if mankind could have a relatively seamless transition to renewables, because hydrocarbons continue to be the most economic and practical forms of energy, individuals will use these until forced to make a transition. A transition forced upon us will not be simple or problem-free.

Renewable Alternatives

Biofuel Alternatives	Electrical Alternatives	Heat Alternatives	Natural Gas Alternatives
Ethanol:	Biomass (wood waste, peat, other)	Biomass (wood waste, peat, other)	Biogas
Cellulosic	Concentrated Solar Power	Concentrated Solar Power	
Corn (Maize)	Fuel Cells	Geothermal	
Sugar Beet	Geothermal	Thermal Solar	
Sugar Cane	Hydroelectric		
Wheat	Ocean Thermal Energy Conversion		
Other crop-based Ethanol	Ocean Wave Energy		
	Offshore Wind Turbines		
Biodiesel:	Onshore Wind Turbines		
Algae	Photovoltaic Solar		
Canola	Tidal Electrical Power		
Flax seed	Thermal Solar		
Jatropha			
Palm Oil			
Soya			
Sunflower			
Tallow (Animal Fat)			
Other crop-based Biodiesel			

Figure 4. Renewable Alternatives
Sources: EIA, Natural Resources Canada, AltaCorp Capital Inc.

We believe it is high time for an "apples to apples" comparison of the various energy technologies and the economics of each. Mankind needs to leverage as high a use of renewables as a first use priority as conventional fossil fuels gets harder to find and produce. However, our society is still driven by economics and individuals make a majority of their decisions based on price.

One can argue that GHG carbon taxes force this issue sooner and to the degree that the tax dollars would be efficiently and effectively be well deployed I would want to carefully consider this. Unfortunately, big governments including national, globalist and big bureaucracies such as the United Nations have had least 70 years to prove themselves almost always prove to be mostly wasteful, ineffective and very often entirely corrupted the longer they are allowed to operate.

Figure 1: Use of carbon tax revenues by high-income OECD countries

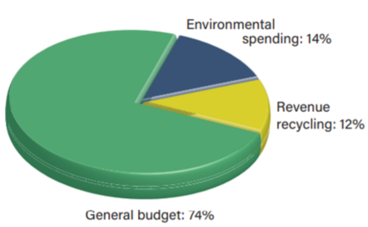
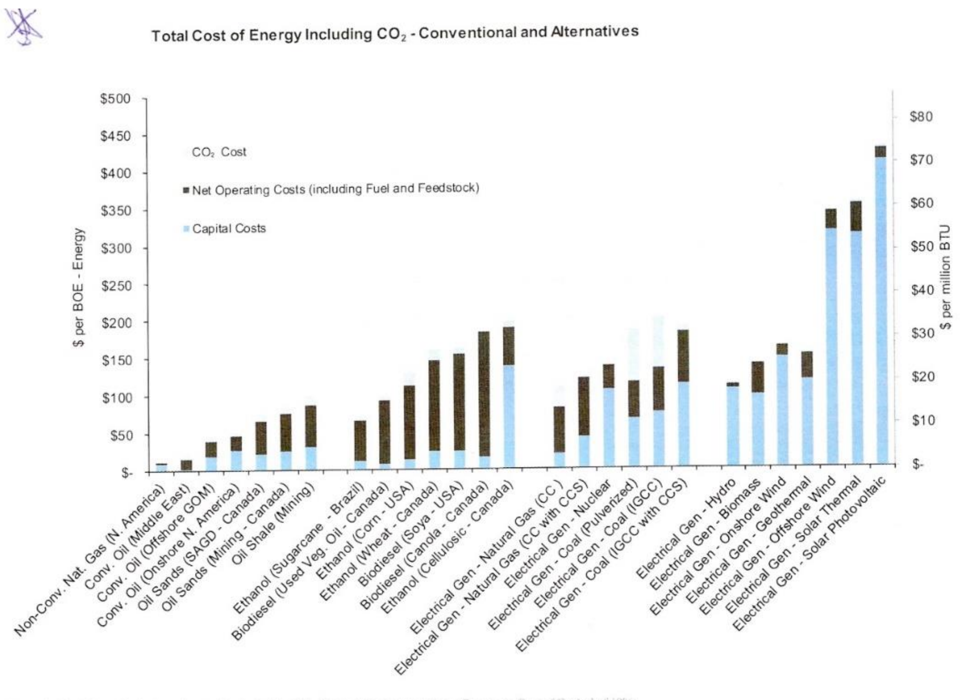


Table 2: Use of carbon tax revenues by high-income OECD countries (latest available data)

Country	Environmental spending (%)	Revenue recycling (%)	General budget (%)
Canada	10	90	0

Enhancing energy literacy and understanding being executed at the local community level has proven far and away better able to outperform if allowed to. Green bonds and such vehicles have shown an ability to facilitate a hybrid solution and balance to global needs and local execution and seem to be an intelligent response (see https://www.paceab.ca/)



- Electricity – 1 MWh = 3,412,000 BTU but at about 33% electrical efficiency we use about 10 MCF or GJ's to generate 1MW
- Light / Medium Oil – 1 Barrel = 5,800,000 BTU
- Natural Gas – 1 mcf = 1,027,000 BTU
- Ethanol – 1 Barrel = 3,563,00 BTU
- Biodiesel – 1 Barrel = 5,359,000 BTU

Cost of Capital

"The capital-intensive nature of many large-scale energy projects, particularly alternatives, can lead to a debate about an appropriate cost of capital to apply in the calculation of energy costs. In our analysis, we have assumed a corporate cost of capital of 10+%, which is in the range of what most alternative energy corporations might be forced to use in major capital investment decisions. However, as accurately indicated by many in the energy debate, we need to consider future generations" access to reasonably priced energy and to a conserved environment. It is important to note that cost of capital – or expected rate of return by an investor – is fundamentally in conflict with future generations because it, by its nature, gives lower value to cash received in the future.

The higher the cost of capital and the further away in time, the lower the value in today's dollar. For instance, at a cost of capital of 10%, a dollar received in 10 years is worth $0.35 today and if received in 20 years it is worth only $0.12 today. The implication here is that it is better to receive the dollar in 10 years rather than in 20 years because it is many times more valuable at the earlier date. The goal in business – in a free market society – is to maximize the net present value (NPV) of assets and the higher the cost of capital, the lower the amount of value that is attributed to future years. This is more than just a way of doing business, it is a fundamental decision-making tool for all individuals”

U.S. Electricity Subsidies

Fuel / End-Use	FY 2007 Net Generation (billion KWh)	Alternative Measures of Subsidy and Support: FY 2007 Subsidy and Support ($mm)	Alternative Measures of Subsidy and Support: Subsidy and Support per Unit of Production ($/MWh)
Coal	1,946	854	0.44
Refined Coal	72	2,156	29.81
Natural Gas and Petroleum Liquids	919	227	0.25
Nuclear	794	1,267	1.59
Biomass (and biofuels)	40	36	0.89
Geothermal	15	14	0.92
Hydroelectric	258	174	0.67
Solar	1	14	24.34
Wind	31	724	23.37
Landfill Gas	6	8	1.37
Municipal Solid Waste	9	1	0.13
Unallocated Renew ables	NM	37	NM
Renew ables (subtotal)	360	1,008	2.80
Transmission and Distribution	NM	1,235	NM
Total	4,091	6,747	1.65

Figure 26. U.S. Electricity Rebates

All of this discussion is to point out the fundamental problem we are facing in our society in that we are driven by maximizing value in today’s dollar and this is forcing us to use the cheapest forms of energy. The result is we mostly use inexpensive hydrocarbons initially, and the more expensive alternatives are being left until they become economically viable or hydrocarbons become too expensive.

A Comment on Green Jobs

“It has been pointed out that renewable energy projects, like solar and wind, create more jobs for every dollar invested than hydrocarbon projects. This is not surprising; from our analysis of the economics of these projects, it would actually be expected. This is because for every BTU of solar and wind energy produced, significantly more money needs to be invested – including labour costs. Although more jobs might be created with renewable energy for every dollar invested, it would in fact be better if *fewer* jobs were produced for every dollar invested. The logic here is: if total costs (including labour) were reduced on a BTU basis then the projects would be more economically-viable and the businesses behind them might become truly sustainable.

To clarify, this somewhat counter-intuitive argument, consider two companies competing in the same business sector and producing the same product (BTUs in this case, but could be any product). One employs 10 people and the other five, but they both produce the same amount of product, have the same financial resources and pay their employees similarly. With everything else being equal, which one will be more successful, grow more rapidly and continue to add jobs? Obviously the lower-cost company, the one with fewer employees per product produced; the BTUs would be produced for lower cost. Should the government subsidize the less efficient company to create more jobs?”

See *The "Green Jobs" Fantasy: Why the Economic and Environmental Reality Can Never Live Up to the Political Promise* Author: Moore, Michal / Winter, Jennifer

Garrett Hardin‟s *Tragedy of the Commons* is well described on Wikipedia:

Central to Hardin's article is an example (first sketched in an 1833 pamphlet by W. F. Lloyd) of a hypothetical and simplified situation based on medieval land tenure in Europe, of herders sharing a common parcel of land, on which they are each entitled to let their cows graze. In Hardin's example, it is in each herder's interest to put the next (and succeeding) cows he acquires onto the land, even if the quality of the common is temporarily or permanently damaged for all as a result, through over grazing. The herder receives all of the benefits from an additional cow, while the damage to the common is shared by the entire group. If all herders make this individually rational economic decision, the common will be depleted or even destroyed to the detriment of all.

The Tragedy of the Hydrocarbons is similar in many ways to the *Tragedy of the Commons*, including:

- The “group” in this tragedy is the billions of humans on the planet and the “commons” are the hydrocarbons that are available to most of mankind. We can equate the grasses on Hardin‟s commons to hydrocarbons; both are a source of energy and a shared resource. The grasses on Hardin‟s commons are the source of energy for the cows (and ultimately the herders); in the Tragedy of the Hydrocarbons the hydrocarbons are the source of energy for the global society.
- Hydrocarbons provide one of the most economic forms of energy available, and therefore, will be consumed preferentially before more expensive alternative forms of energy.
- The consumption of hydrocarbons increase the quality of life for an individual through low-cost transportation, food, goods and services. The individual receives the full benefit of the use of energy, but shares damage to the commons

with billions of others. The damage to the commons in this tragedy is the reduction of fossil fuel reserves. That is, increasing consumption will reduce the amount available for others, including future generations.

- Conversely, consider an individual who chooses to use a more-expensive and completely-renewable form of energy, say wind and solar. Although commendable, this person (**or country when considering how the Paris Accord attempts to legislate a huge advantage to China and utterly punish and disadvantage the G7**) bears the full burden of higher energy costs and practical limitations of these forms of energy. The benefits this individual provides to society – less pollution and the preservation of resources – are shared with billions of other individuals. The net result is the individual pays a large cost for a wise choice but gains essentially no personal benefit (when spread over billions of others) from his/her efforts.
- This is the tragedy: individuals will make the choice to use the cheaper non-renewable hydrocarbons because it is best for them at this moment. It would be better for society if this was not the case, but this is how individuals most often act under the circumstances.
- To reiterate what was stated earlier, mankind will have to dramatically change its collective thinking to avoid this tragedy and adopt the use of alternatives before we are forced to change under more challenging circumstances."

4 Renewable Energy in Canada

4.1 Capacity

For the first time since conducting this analysis, we find that Canada's renewable energy capacity exceeds 100,000 MW. This capacity is used to convert renewable energy into electricity, heat and liquid fuels. Most of Canada's renewable energy capacity (85%) is electric. An additional 13% is thermal, and the remaining 2% is liquid.

Figure 2 and Table 1 break down Canada's energy capacity by resource type. Almost three quarters of this capacity is hydro power (74%, or 75,430 MW). The remaining quarter is dominated by biomass (16%) and wind (8%) facilities. Installed solar photovoltaic arrays account for 1% of capacity. A number of other energy sources, such as biogas, solar thermal and earth energy account for the remaining 1%. However, it should be noted that many of the sources of energy in the "other" category (e.g., solar thermal and earth energy) are under-represented in our database.

Source: www.cieedac.sfu.ca April 2015

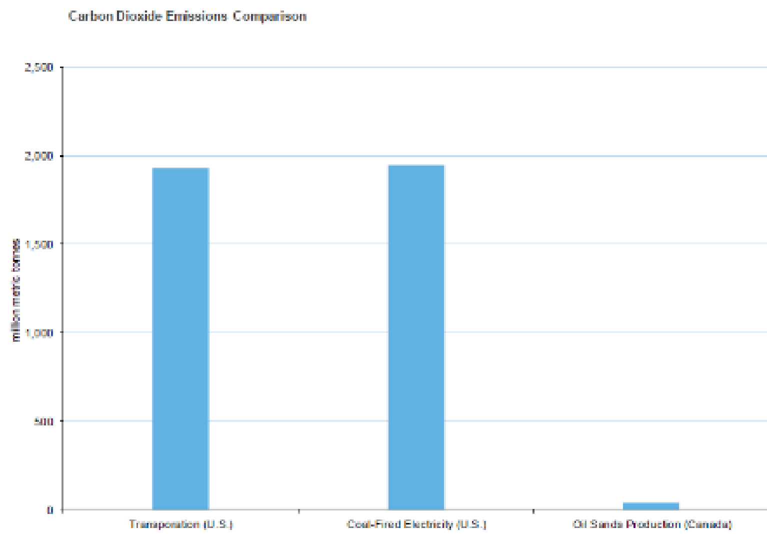
Growth in Alternatives to 2100 – the Long Term

"If we assume that growth in energy consumption continues at 1.2%, the total demand in 2100 will grow by over 195% to 1,482 quadrillion BTUs from approximately 502 quadrillion in 2009. The absolute increase of 980 quadrillion BTUs over this time period represents over *nine times* the amount of energy currently consumed in the United States. Little analysis is required to determine that this amount of energy generation is not possible using current technologies; few would argue it could be achieved". Indeed Ted Trainer has extensively researched and argued this. For the sake of brevity we will not detail Trainers arguments and research here. For the facts and figures, readers are referred to Trainers books and essays. But the critical findings of his research can be easily summarised. After examining the evidence on varieties of solar, wind, hydro, biomass, and other kinds of energy sources, as well as energy storage and distribution systems up to and including 2016, Trainer (see http://thesimplerway.info/ or see http://richardheinberg.com/museletter-286-100-renewable-energy-what-we-can-do-in-10-years) concludes that figures do not support wishful thinking; that is to say, they do not support the argument that renewable energy can sustain G20 society current lifestyles. This is because the enormous (and globally growing) quantities of electricity, thermal and liquid fuels required by consumer societies today cannot be provided for by any current mixture of renewable energy sources, each of which suffers from various limitations arising out of such factors as intermittency of supply, storage problems, resource limitations (e.g. land for biomass competing with food production or rare earth, lithium and cobalt resource constraints) and inefficiency issues. Others disagree…see a team of engineers headed by Marc Jacobson at Stanford have created the blueprints for countries to move to 100% renewable energy one city and country at a time. To read Jacobson's detailed work to convert 139 countries see https://stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html

Much is required and in some order of priority:

1. Drop in consumption? Without question
   a. Quantum leaps are required.
   b. On site cogeneration within buildings if widely adopted is one such potential quantum leap as it has been measured and shown to have the potential to decrease overall energy use by about 23%.
2. Increase in alternatives? Absolutely! How will we get there?
   a. The general public needs an understanding and consensus of why this needs to be rapidly pursued now (energy literacy)

b. We need to stop subsidizing all forms of energy so real economics prevail and energy innovation can flourish



Below I leverage and comment on Dr. Tom Murphy's excellent analysis and web site http://physics.ucsd.edu/do-the-math/ Dr. Murphy's work attempted to briefly and concisely profile viable alternatives to fossil fuels this century. In doing so of course he has not exhausted all possibilities.

"The primary "mission" of late has been to sort possible future energy resources into boxes labeled "abundant," "potent" (able to support something like a quarter of our present demand if fully developed), and "niche," which is a polite way to say puny. In the process, I have clarified in my mind that a significant contributor to my concerns about future energy scarcity is not the simple quantitative scorecard. After all, if it were that easy, we'd be rocking along with a collective consensus about our path forward. Some comments have asked: "If we forget about trying to meet our total demand with one source, could we meet our demand if we add them all up?" Absolutely. In fact, the abundant sources technically need no other complement. So on the abundance score alone, we're done at solar, for instance. But it's not that simple, unfortunately. While the quantitative abundance of a resource is key, many other practical concerns enter the fray when trying to anticipate long-term prospects and challenges — usually making up the bulk of the words in prior posts" Dr. Murphy.

For example, it does not much matter that Titan has enormous pools of methane unprotected by any army (that we know of!). The gigantic scale of this resource makes our Earthly fossil fuel allocation a mere speck. But so what? Practical considerations mean we will never grab this energy store. Likewise, some of our terrestrial sources of energy are super-abundant, but just a pain in the butt to access or put to practical use.

In this post, we will summarize the ins and outs of the various prospects. Interpretation will come later. For now, let's just wrap it all up together.

The Matrix

Would you like to know what the matrix is? Okay. I'll tell you — in a bit. For each of the major energy hopefuls I have discussed on Do the Math, I characterize their various attributes in a three-tier classification: adequate (green); marginal (yellow); or insufficient (red) — possibly a showstopper. The scheme is qualitative, and I am sure some will disagree with my assignments. Before I go any further, let me say that I will not entertain comments griping about why I made a certain square the color I did. I won't have time to respond at that level, given that there are 200 colored boxes in the matrix. But the beauty is, you can change the matrix *any way you see fit* and make your own custom version. Go buy some crayons today! The matrix I've created is not without its biases and subjectivity. Whose would be?

Okay, I'll keep the suspense going a bit by describing the fields.

Abundance: This is essentially the "abundant," "potent," and "niche" classification scheme reflected in the preceding posts. Green means that the resource can in principle produce far more power than we currently use and keep it up for many centuries. Red means a bit-player at best. Yellow is the stuff that can be useful, but is incapable of carrying the full load — not that we require everything to do this. We can tolerate a mix of items, but will not get far by mixing reds together.

Difficulty: This field tries to capture the degree to which a resource brings with it large technical challenges. How many PhDs does it take to run the plant? How painful is it to maintain or keep churning? This one might translate into economic terms: difficult is another term for expensive.

Intermittency: Green if rock-steady or there whenever we need it. If the availability is beyond our control, then it gets a yellow at least. The possibility of going without for a few days earns a red.

Demonstrated: I don't mean on paper, and I don't mean a prototype that exhibits some of the technology. To be green, this has to be commercially available today and providing useful energy.

Electricity: Can the technology produce electricity? Most of the time, the answer is yes. Sometimes it would make no sense to try. Other times, it is seriously impractical.

Heat: Can the resource produce direct heat? Yellow if only through electric means.

Transport: Does the technology relieve the liquid fuels crunch? Anything that makes electricity can power an electric car, earning a yellow score. Liquid fuels are green. Some may get tired of the broken record in the descriptions that follow that a particular resource does not help transportation, wanting to shout "electric cars, fool" every time I say it. But our large-scale migration to electric cars is not in the bag. They may remain too expensive to be widely adopted. Meanwhile, this does not help air travel or heavy transport.

Acceptance: Is public opinion (I can really only judge U.S. attitudes) favorable to this method? Will there likely be resistance—whether justified or not?

Backyard?: Is this something that can be done domestically, in one's backyard or small property, managed by the individual?

Efficiency: Over 50% gets the green. Below about 10% gets red. It's not the most important of criteria, as the abundance score incorporates efficiency expectations. But we will always view low efficiency negatively.

(Editors comment: I think this matrix is the best I've seen…I would recommend adding an environmental impact category with the capability of negative scores for degradation of the environment or large land use for example…Fossil fuels do not hold up nearly so well when this is added)

Okay, enough holding out—here's the matrix.

	abundance	difficulty	intermittency	demonstrated	electricity	heat	transport	acceptance	backyard?	efficiency	Score
Solar PV						via electric	via electric				5
Solar Thermal			some storage				via electric				5
Solar Heating			some storage								4
Hydroelectric			seasonal flow			via electric	via electric	not universal	micro-hydro		4
Biofuel/Algea		gunk/disease		some R&D	mis-spent				small scale?		4
Geothermal/Electricity	hotspots						via electric				4
Wind						via electric	via electric	noise, birds, eyesore			3
Artificial Photosynth.		catalysts		active devel.	mis-spent				?		3
Tidal			daily/monthly variations			via electric	via electric				3
Conventional Fission		high-tech					via electric	waste/fear			2
Uranium Breeder		high-tech		military			via electric	proliferation			2
Thorium Breeder		high-tech					via electric	waste/fear			2
Geothermal/Depletion		deep drill		rarely?				deep wells	impractical		2
Geothermal/Heating		deep drill		rarely?				deep wells	impractical		1
Biofuel/Crops	food cellulosic	annual harvest	seasonal	ethanol, etc. R&D effort	mis-spent			food/land competition	small beans		1
OceanThermal		access/ maintenance				via electric	via electric				1
Ocean Current		access/ maintenance				via electric	via electric				1
Ocean Waves			storms/lulls	many one-off designs		via electric	via electric	eyesore			1
D-T Fusion	lithium	future-tech					via electric	trit/neutron contamination			1
D-D Fusion		farther future					via electric				1

Yellow boxes tend to deserve explanation. It is usually clear why something would swing red or green, but yellow often has several things tugging at it. If green boxes are given a +1 score, yellow boxes zero, and red boxes -1, adding the boxes with equal weight yields the scores on the right, by which measure the table is sorted: best to worst. The only place I cheated was to give D-D fusion a -2 for difficulty. It's the hardest thing on the list, given our decades of massive effort invested to date on D-T fusion, while D-D is too hard to even attempt.

Now, equal weighting on all ten criteria is boneheaded. But the assessment is imprecise enough not to warrant a more elaborate weighting scheme. I do not stand firm behind the order that results, and am half-tempted to monkey with weighting schemes until a more preferred order emerges. But I would be cooking the books to further match my preferences. Feel free to weight any way you see fit, and change anything else while you're at it. Just remember. No griping.

Fossil Fuels, Compared

	abundance	difficulty	intermittency	demonstrated	electricity	heat	transport	acceptance	backyard?	efficiency	Score
Petroleum	for now										8
Natural Gas	for now						buses, trucks via electric			for heat elec/transport	8
Coal	for now						via electric trains?				7

Note that **conventional fossil fuels**, matrixed-out above, score *green in almost every category*, except—unfortunately—abundance. The efficiency is high for direct heating (most often natural gas), and middling for electricity or transport. Coal gets no points for transportation, and natural gas is of limited use here (although the bus I'm riding as I type this is powered by natural gas, so I can't entirely nix its transportation capability). All things considered, *all* of the fossil fuels get a score of 7 or 8. Note the **striking gap** we face between fossil fuels and their alternatives, topping out at a score of 5. One might ding the fossil fuels a point or two for their greenhouse gas contributions, closing the gap a bit. None of the options in the alternatives matrix are intrinsic carbon emitters.

Quick Lessons

Looking at some of the main trends, **very few** options are both **abundant and easy**. Solar PV and solar thermal qualify. A similar exclusion principle often holds for abundant and demonstrated/available. There is a reason why folks (myself included) like solar.

Intermittency mainly plagues **solar** and **wind** resources, with mild inconvenience appearing for many of the natural sources.

Electricity is easy to produce. We have loads of ways to do it, and are likely to pick the easiest/cheapest. We won't necessarily get far down the list if we're covered by things at the top end (assuming my rankings have any validity and some economic correlation).

Transport is hard. Concerns over peak oil played a *huge* role in making me sit up to pay attention to our energy challenges. Electric cars are the most obvious way out, but don't do much for heavy shipping by land or sea, and leave airplanes on the ground.

Few things face serious barriers to **acceptance**: especially when energy scarcity is at stake.

A **few options** are available for the **homestead**. A passive solar home with PV panels, wind, and some method to produce liquid fuels on site would be a dream come true. Here's hoping for artificial photosynthesis!

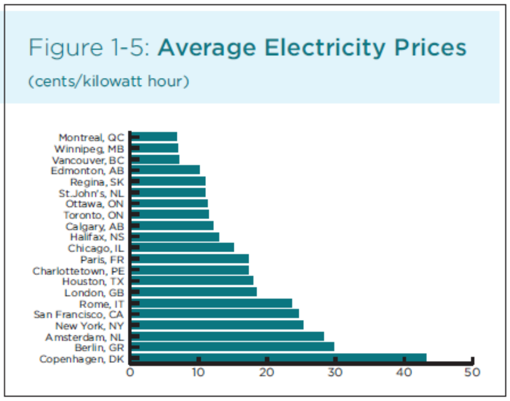
The missing category here is **cost**, although difficulty may be an imperfect proxy. As a result, some of the high-scoring options may be more costly than we'd like. Actually, some of the lowest-scoring options are the costliest! If you're expecting that we'll replace fossil fuels *and* do it on the cheap, you might as well learn to bawl on the floor kicking and pounding your fists, tears streaming. This is our predicament. We have to buck up and deal with it, somehow.

Individual Energy Sources Discussion:

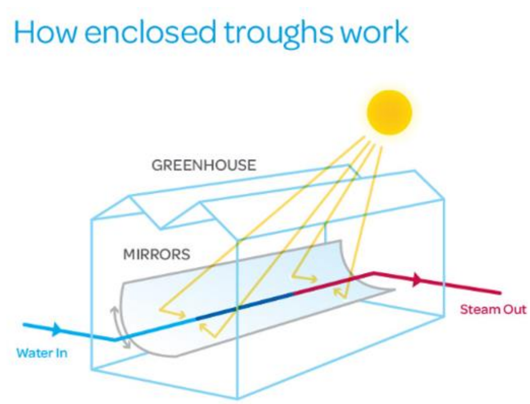
For each topic, the link at the beginning points to a more complete discussion on Do the Math. Here, I just briefly characterize each resource in relation to the matrix criteria.

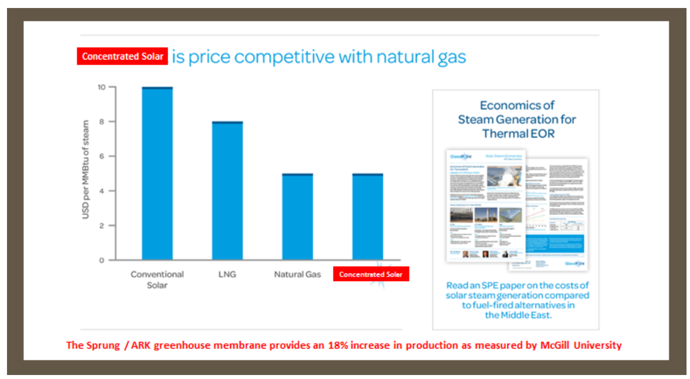
Solar PV: Covering only 0.5% of land area with 15% efficient PV panels provides the annual energy needs of our society, qualifying solar PV as abundant. It's not terribly difficult to produce; silicon is the most abundant element in Earth's crust, and PV panels are being produced globally at 25 GW peak capacity per year (translating to 5 GW of average power added per year). Intermittency is the Achilles Heel of solar PV, requiring storage solutions if adopted at large scale. Solar PV produces electricity directly, which *could* be converted to heat or transport. Most people do not object to solar PV on rooftops or over parking areas, or even in open spaces (especially desert). I've got some on my garage roof as we speak (with storage), so they're well-suited to individual operation/maintenance. Clocking in at an efficiency of 15%, don't expect PV to vastly exceed this ballpark.

> ***Germany's Solar Experiment Collapses*** *Financial Post*
>
> *Germany once prided itself on being the "photovoltaic world champion" doling out generous subsidies – totalling more than US$130 billion, according to research from Germany's Ruhr University – to citizens to invest in solar energy. But now the German government is vowing to cut the subsidies sooner than planned, and to phase out support over the next five years. What went wrong?*
>
> *According to Der Spiegel, even members of Chancellor Angela Merkel's staff are now describing the policy as a massive money pit. Philipp Rosler Germany's Minister of Economics and Technology, has called the spiralling solar subsidies a "threat to the economy."*
>
> *Germany's enthusiasm for solar power is understandable. We could satisfy all of the world's energy needs for an entire year if we could capture just one hour of the sun's energy. Even with the inefficiency of current PV technology, we could meet the entire globe's energy demand with solar panels by covering 250,000 square kilometres, about 2.6% of the Sahara Desert. (Electricity transmission too, unfortunately is very expensive and inefficient)*
>
> *Unfortunately, Germany – like most of the world – is not as sunny as the Sahara. And, while sunlight is free, panels and installation are not. Solar power currently is at least four times more costly than energy produced by fossil fuels (but it has been dropping and fossil fuel cost had been going up). It also has the distinct disadvantage of not working at night, when much electricity is consumed.*
>
> *In the words of the German Association of Physicists, "solar energy cannot replace any additional power plants." On short, overcast winter days, Germany's 1.1 million solar-power systems can generate no electricity at all. The country is then forced to import considerable amounts of electricity from nuclear power plants in France and the Czech Republic. When the sun failed to shine last winter, one emergency back-up plan powered up an Austrian oil fired plant to fill the supply gap.*
>
> *Indeed, despite the massive investment, solar power accounts for only about 0.3% of Germany's total energy. This is one of the key reasons why Germans now pay the second-highest price for electricity in the developed world (exceeded only by Denmark, which aims to be the "world wind-energy champion").*



Solar Thermal: Achieving comparable efficiency to PV, but using more land area, generating steam or electricity from concentrated solar thermal energy automatically fits in the abundant category. It's relatively low-tech: shiny curved mirrors tracking on (often) one axis, heating oil or other fluid to run a plain-old heat engine. Intermittency can be mitigated by storing thermal energy, perhaps even for a few days. Because a standard heat-engine follows, fossil fuels can supplement in lean times using the same back-end. A number of plants are already in operation, producing cost-competitive electricity — and heat for industrial users that need it, etc. As with so many of the alternatives, transportation is not directly aided. Public acceptance is no worse than for PV, etc.

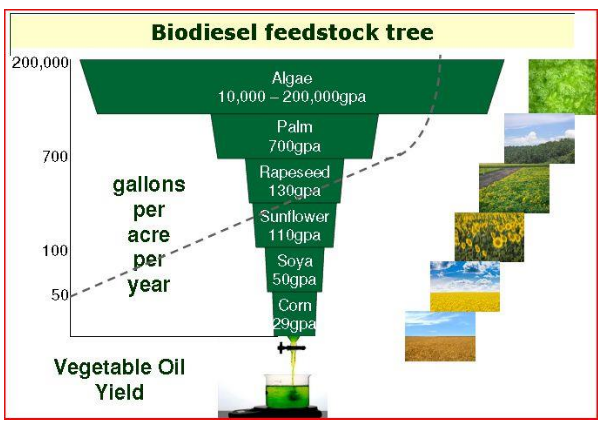




Solar Heating: On a smaller scale, heat collected directly from the sun can provide domestic hot water and home heating. In the latter case, it can be as simple as a south-facing window. Capturing and using solar heat effectively is not particularly difficult, coming down to plumbing, insulation and ventilation control. Technically, it might be abundant, but since it is usually restricted to building footprints (roof, windows), I take it down a notch. There will be lean days, but my friends in Maine do not complain about their solar heating comfort (with occasional propane backup). Solar heating is useless for electricity or transport, but has no difficulty being accepted and almost by definition is a backyard-ready technology.

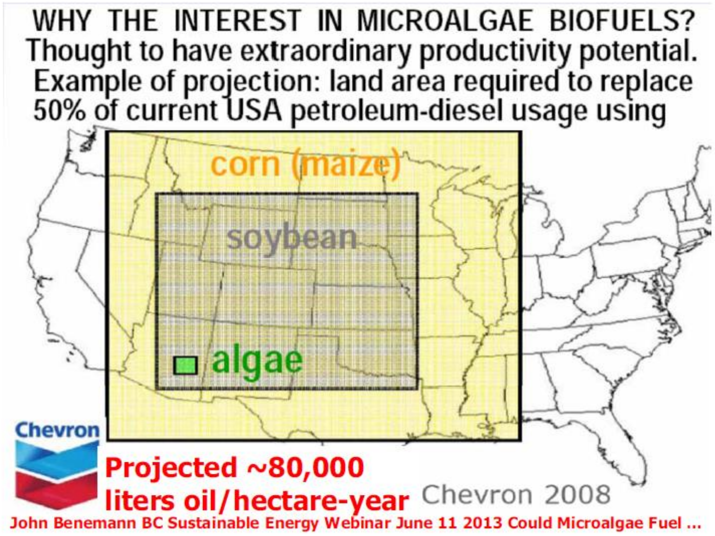
Hydroelectric: We have seen that super-efficient hydroelectric is doomed to remain a small player (in the rubric that we maintain today's energy consumption levels). It's the low-hanging fruit of the renewable world, and has therefore already seen large-scale development. It has seasonal intermittency (typical capacity factor for a hydro plant is 40%), does not directly provide heat or transport, and can only rarely be implemented personally, at home. Acceptance is fairly high, although silting and overall maintenance—together with habitat destruction—are huge causes of concern See: **AP: At least 1,680 dams across the US pose potential risk** [https://apnews.com/f5f09a300d394900a1a88362238dbf77.](https://apnews.com/f5f09a300d394900a1a88362238dbf77) Remember producing one cubic mile of oil equivalent (CMO) of energy a year from **hydro power** will require the construction of another 153 of China's Three Gorges Dams – or one every four months for the next 50 years. But this number of undammed rivers do not exist.

Biofuels from Algae: It may surprise some to see this entry rank as highly as it did in my admittedly unsophisticated scoring scheme. Because it captures solar energy — even at < 5% efficiency — the potential scale is automatically enormous. But it's not easy, at present. Dealing with slime will bring challenges of keeping the plumbing clean, possible infection in a genetic arms race with evolving viruses, contamination by other species, etc. At present, we don't have that magic algal sample that secretes the fuels we want. Heady talk of genetic engineering pledges to solve these problems, but we're simply not there yet and cannot say for sure that we will get there. Otherwise, the ability to provide transportation fuel is the big draw. Heat may also be efficiently produced. Can it be done in the backyard? I could imagine something in the yard or garage, but care and feeding and refining the product may be difficult but then again maybe not see https://www.digitaltrends.com/cool-tech/biorreactor-co2-trees-400x/



Biodiesel Production Numbers:

- 227 litres of biodiesel from every acre of soybeans
- 473 litres for every acre of rape seed
- 530 litres for every acre of mustard
- 2,460 litres for every acre of palm
- An acre of algae can produce 18,927 litres of biodiesel
- Research indicates that enough biodiesel can be produced from 7 million square acres (size of Hawaii) of algae biodiesel in salt water to produce enough biodiesel for all US transportation.



The tax credit lapsed at the end of 2009 and biodiesel volumes dropped dramatically.

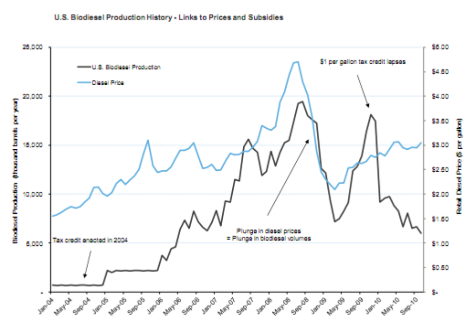
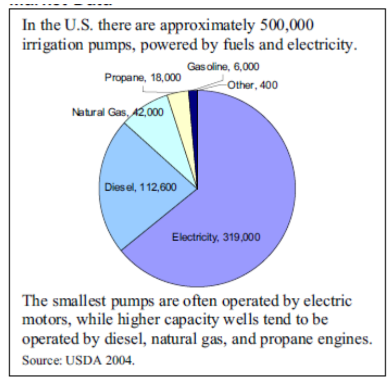


Figure 27. Biodiesel Production Reliant on High Diesel Prices and Subsidies
Sources: EIA, Bloomberg, National Biodiesel Board, AltaCorp Capital Inc.



Geothermal Electricity: This option makes sense primarily at geological hotspots, which are rare. It will not scale to be a significant part of our entire energy mix. Aside from this, it is relatively easy, steady and well-demonstrated in many locations. It can provide electricity, and obviously direct heat — although far from heat demand, generally. It provides no direct help on transportation. Objections are slim to non-existent. I don't think houses tend to be built on the hotspots, so don't look for it in a backyard near you.

Geothermal power plants cost more money than natural gas facilities. For some perspective, consider the Neal Hot Springs plant in Oregon that was constructed in 2012 for [$139 million for 22 megawatts of production].

The Shepard natural gas power plant in Calgary began operating recently with a total cost of [$1.4 billion for 800 megawatts of electricity]. In this comparison, the geothermal facility costs three times as much per megawatt of power and the Shepard plant was very much on the high side of averages.

Wind: Wind is a sensible option that I imagined would float higher in the list than it did. It's neither abundant nor scarce, being one of those options that can provide a considerable fraction of our present needs under large-scale development. It's pretty straightforward, reasonably efficient, and demonstrated the world over in large farms. The biggest downside is its intermittency. It will not be unusual to have a few days in a row with little or no regional input. The most wind turbines have been proven to operate is about 35% of the hours in a year anywhere in the world (lots of claims of otherwise that do not prove out). Like so many other things, electricity is naturally produced, while heat and transport is only available via electricity. I sense that objections to wind are more serious than for many other alternatives. Windmills tend to be located in prominent places (ridge-tops) where they are extremely visible and scenery-altering. You can't hide wind in a bowl, or you end up hiding from the wind at the same time. Another built-in conflict emerges on wind-rich coastlines, where many like to take in unspoiled scenery. There is lots of environmental impact with the birds and bats. Small-scale wind isn't very viable in your own backyard as of yet.

Artificial Photosynthesis: A very appealing future prospect for me is artificial photosynthesis, combining the abundance of direct solar with the self-storing flexibility of liquid fuel. Intermittency is thus eliminated to the extent that annual production meets demand: storage of a liquid fuel for many months is possible. The dream result of a panel sitting on your roof that drips liquid fuel could provide both heating and transportation fuel. In a pinch, one could also produce electricity this way, but what a waste of precious liquid fuel, when we have so many other ways to make electricity! The catch is that it doesn't exist yet, that it may never exist, and that feeding it the right ingredients and processing/refining the fuel may eliminate the backyard angle. Still, we all have to have *something* to gush over. For some, it's thorium and for others it's fusion, etc. This one excites me by its potential to satisfy so many purposes.

Tidal Power: Restricted to select coastal locations, tidal will never be a large contributor on the global scale. The resource is intermittent on daily and monthly scales, but in a wholly predictable manner. Extracting tidal energy is not terribly hard – sharing technology with similarly efficient hydroelectric installations — and has been demonstrated in a number of locations around the world. It's another electricity technique, with no direct offering of heat or transportation. No unusual level of societal objection exists, to my knowledge, but it's not something you will erect in your backyard and expect to get much out of it.

Conventional Fission: Using conventional uranium reactors and conventional mining practices, nuclear fission does not have the legs for a marathon. On the other hand, it is certainly well-demonstrated, and has no problems with intermittency — unless we count the fact that it has trouble *being* intermittent in the face of variable load. Compared to other options, nuclear runs a tad on the high-tech side. By this I mean that design, construction, operation and emergency mitigation require more brains and sophistication than the average energy producer. Nuclear fission directly produces heat (seldom utilized), and is primarily used to generate electricity via the standard steam-driven heat engine, but offers no direct help on transportation. Acceptance is mixed. Germany plans to phase out its nuclear program even though they are serious about carbon reduction. No new plants have been built in the U.S. for over thirty years in part due to public discomfort. Some of this is irrational fear over mutant three-eyed fish and the like, but some is genuine political difficulty relating to the pesky waste problem that no country has yet solved to satisfaction. Nuclear power is not possible on a personal scale.

Uranium Breeder: Extending nuclear fission to be able to use the 140-times more abundant ^{238}U (rather than 0.7% ^{235}U) gives uranium fission the legs to run for at least centuries if not a few millennia, so abundance issues disappear. Breeding has been practiced in military reactors, and indeed some significant fraction of the power in conventional uranium reactors comes from ^{238}U turned ^{239}Pu. But no commercial power plants have been built to deliberately access the bulk of uranium, turning it into plutonium at scale for the purpose of power production. Public acceptance of breeders will face even stiffer hurdles because plutonium is more easily separated into bomb material than is ^{235}U, and the trans-uranic radioactive waste from this option is nastier than for the conventional cousin.

Thorium Breeder: Thorium is more abundant than uranium, and only comes in one flavor naturally, so that abundance is not an issue. Like all reactors, thorium reactors fall into the high-tech camp, and include new challenges (e.g., liquid sodium) that conventional reactors have not faced. There have been a few instances of small-scale demonstration, but nothing in the commercial realm, so that we're probably a few decades away from being able to bring thorium online. Public reaction will be likely be similar to that for conventional nuclear: not a show stopper, but some resistance on similar grounds. It is not clear whether the newfangled aspect of thorium will be greeted with suspicion or with an embrace. Though also a breeding technology (making fissile ^{233}U from ^{232}Th), the proliferation aspect is severely diminished for thorium due to highly radioactive ^{232}U by-product and virtually no easily separable plutonium. Of the future nuclear prospects, I am most optimistic about this one — although it's no nirvana to me.

Geothermal Heating with Depletion: A vast store of thermal energy sits in the crust, locked in the rock and moving slowly outward. Being the impatient lot that we are, we could drill down and grab the energy out of the rock on our own schedule, effectively mining heat as a one-time resource. In the absence of water flow to convect heat around, dry rock will deplete its heat within 5–10 meters of the borehole in a matter of a few years, requiring another hole 10 meters away from the first, and so on and so on. I classify this as moderately difficult, requiring a never-ending large-scale drilling operation across the land. The temperatures are pretty marginal for running heat engines to make electricity with any respectable efficiency (especially given so many easier options for electricity), but at least the thermal resource will not suffer intermittency problems during the time the hole is still useful. Given its inconvenience (kilometers of drilling), I do not know if examples abound of people having tried this *for the purpose* of providing heat in arbitrary (not geologically hot) areas. Public acceptance may be less than lukewarm given the scale of drilling involved, dealing with tailings and possibly groundwater contamination issues on a sizable scale. While such a hole could fit in a backyard, it would be far more practical to use the heat for clusters of buildings rather than for just one — given the amount of effort that goes into each hole (and considering short-term lifetime of each hole). I gave this technique high marks for efficiency if used for heat, but it would drop to reddish-yellow if we tried to use this resource for electricity.

Geothermal Heating, Steady State: If we turn our noses up at depletion-based geothermal heat, steady state offers far less total potential, coming to about 10 TW of flow if summed across all land. And to access temperatures hot enough to be useful for heating purposes, we're talking about boreholes at least 1 km deep. It is tremendously challenging to cover any significant fraction of land area with thermal collectors 1 km deep. So I am probably being too generous to color this one yellow for the abundance factor. That's okay, because I'm hitting it hard enough on the other counts. To gather enough steady-flow heat to provide for a normal U.S. home's heat, the collection network would have to span a square 200 m on a side at depth, which seems nightmarish to me. But at least depletion would not be an issue in this circumstance. Otherwise, this category shares similar markings and rationale as the depletion scenario.

Biofuels from Crops: We've seen that corn ethanol is a loser of a scheme on energy grounds, although sugar cane and vegetable oils fare better. But these compete with food production and arable land availability, so biofuels from crops can only graduate from "niche" to "potent" in the context of plant waste or cellulosic conversion. I have thus split the abundance and demonstration in two: food crop energy is demonstrated but severely constrained in scale. Celluosic matter becomes a potent source, but undemonstrated (perhaps this should even be red). I do not label the prospect as an easy one, because growing and harvesting annual crops on a relevant scale constitutes a massive, perpetual job. If exploiting fossil fuels is akin to spending our inheritance, growing and harvesting our energy on an annual basis is like getting a real job — a real *hard* job. The main benefit of biofuels from crops is that we get a liquid fuel out of it — so hard to come by via other alternatives. Public acceptance hinges on competition with food or just land in general. Scoring only about 1% efficient at raking in solar energy, this option requires commandeering massive tracts of land. A small-time farmer may make useful amounts of fuel for themselves in their back "yard," if refining does not create a bottleneck.

This www.ARKltd.net biodiesel refiner makes 150 litres of the finest quality of biodiesel every 48 hours by turning nine valves in that time!

HOW GREEN ARE BIOFUELS?

Biofuels are getting a bad rap as stories of rising food prices and shortages fill the news. But the environmental, energy and land use impacts of the crops used to make the fuels vary dramatically. Current fuel sources – corn, soybeans and canola – are more harmful than alternatives that are under development.

FUEL SOURCES

CROP	USED TO PRODUCE	GREENHOUSE GAS EMISSIONS* Kilograms of carbon dioxide created per mega joule of energy produced	USE OF RESOURCES DURING GROWING, HARVESTING AND REFINING OF FUEL: WATER	FERTILIZER	PESTICIDE	ENERGY	PERCENT OF EXISTING U.S. CROP LAND NEEDED TO PRODUCE ENOUGH FUEL TO MEET HALF OF U.S. DEMAND	PROS AND CONS
Corn	Ethanol	81-85	high	high	high	high	157%-262%	Technology ready and relatively cheap, reduces food supply
Sugar cane	Ethanol	4-12	high	high	med	med	46-57	Technology ready, limited as to where will grow
Switch grass	Ethanol	-24	med-low	low	low	low	60-108	Won't compete with food crops, technology not ready
Wood residue	Ethanol, biodiesel	N/A	med	low	low	low	150-250	Uses timber waste and other debris, technology not fully ready
Soybeans	Biodiesel	49	high	low-med	med	med-low	180-240	Technology ready, reduces food supply
Rapeseed, canola	Biodiesel	37	high	med	med	med-low	30	Technology ready, reduces food supply
Algae	Biodiesel	-183	med	low	low	high	1-2	Potential for huge production levels, technology not ready

* Emissions produced during the growing, harvesting, refining and burning of fuel. Gasoline is 94, diesel is 83.

Source: Martha Groom, University of Washington; Elizabeth Gray, The Nature Conservancy; Patricia Townsend, University of Washington; as published in Conservation Biology SEATTLE P-I

Source: http://seattlepi.nwsource.com/dayart/20080503/biofuels_compare.gif

Ocean Thermal: The ocean thermal resource uses the 20–30°C temperature difference between the deep ocean (a few hundred meters down) and its surface to drive a ridiculously low-efficiency heat engine. The heat content is not useful for warming any home (it's not hot). But all the same, it's a vast resource due to the sheer area of the solar collector. Large plants out at sea will be difficult to access and maintain, and transmitting power to land is no picnic either. The resource suffers seasonal intermittency at mid-latitudes, but let's imagine putting these things all in the tropics to get around this. Sound hard, you say? Well yeah! That's part of what makes ocean thermal difficult! No relevant/commercial scale demonstration exists. Like so many others, this is electricity only (and this time, far from demand). Probably nobody cares what we put to sea: out of sight, out of mind. Ocean thermal is not a backyard solution!

Ocean Currents: Large-scale oceanic currents are slower than wind by about a factor of ten, giving a kilogram of current 1000 times less power than a kilogram of wind. Water density makes up the difference to make ocean current comparable to wind in terms of power per rotor area. Not all the ocean has currents as high as 1 m/s, so I put the total abundance in the same category as wind. Maybe accessing a thicker column of water than we can for wind should bump ocean currents up a bit, but the currents are relatively confined to surfaces. But why dunk a windmill underwater where it's far from demand and difficult to access and maintain, when a comparable power can be had in dry air? So I classify this as difficult. On the plus side, the current should be rock solid, eliminating intermittency worries, unlike wind. Still, not one bit of our electricity mix comes from ocean currents at present, so it cannot be said to have been meaningfully demonstrated. For the remaining categories: it's electricity only; who cares what's underwater; and no backyard opportunity.

Ocean Waves: While they seem strong and ever-present, waves are a linear-collection phenomenon, and not a real phenomenon. So there really isn't that much arriving at shores all around the world (a few TW at best). It's not particularly difficult to turn wave motion into useful electricity at high efficiency, and the proximity to land will make access, maintenance and transmission far less worrisome than for the previous two cases. There *will* be some intermittency — largely seasonal — as storms and lulls come and go. I've seen a diverse array of prototype concepts and a few are being tested at commercial scale. So this is further along than the previous two oceanic sources, but not so much as to get the green light. There will be moderate push-back from people whose ocean views are spoiled, or who benefit from natural wave energy hitting the coast. There are no waves in my backyard and I hope to keep it this way!

D-T Fusion: The easier of the two fusion options, involving deuterium and tritium, represents a longstanding goal under active development for the last 60 years. The well-funded international effort, ITER, plans to accomplish a 480 second pulse of 500 MW power by 2026. This defines the pinnacle of **hard**. Fusion brings with it numerous advantages: enormous power density; moderate radioactive waste products (an advantage?!); abundant deuterium (though tritium is zilch); and surplus helium to liven up children's parties. Fusion would have no intermittency issues, can directly produce heat (and derivative electricity), but like the others does not directly address transportation. The non-existent tritium can be knocked out of lithium with neutrons, and even though we are not awash in lithium, we have enough to last many thousands of years. We might expect some public opposition to D-T fusion due to the necessary neutron flux and associated radioactivity. Fusion is the highest-tech energy we can envision at present, requiring a team of well-educated scientists/technicians to run — so don't plan on building one in your backyard, unless you can afford to have some staff PhDs on hand.

D-D Fusion: Replacing tritium with deuterium means abundance of materials is no concern whatsoever for many billions of years. As a trade, it's substantially harder than D-T fusion (or we would not even consider D-T). D-D fusion requires higher temperatures, making confinement that much more difficult. It is for this reason that I gave D-D fusion a -2 score for difficulty. It's not something we should rely upon to get us out of the impending energy pinch, which is my primary motivation.

End of an Era

Not only does this conclude the end of the phase on Do the Math where we evaluate the quantitative and qualitative benefits and challenges of alternatives to fossil fuels, it also points to the fact that we face the end of a golden era of energy. Sure, we managed to make scientific and cultural progress based on energy from animals, slaves and firewood prior to discovering the fossil fuels. But it was in unlocking our one-time inheritance that we really came into our own. Soon, we will see a yearly decrease in our trust fund dividend, forcing us to either adapt to less or try to fill the gap with replacements. What this post and the series preceding it demonstrates is that we do not have a delightful menu from which to select our future. Most of the options leave a bad taste of one form or the other.

When I first approached the subject of energy in our society, I expected to develop a picture in my mind of our grandiose future, full of alternative energy sources like solar, wind, nuclear, biofuels, geothermal, tidal, etc. What I got instead was something like this matrix: full of inadequacies, difficulties and showstoppers. Our success at managing the transition away from fossil fuels while maintaining our current standard of living is far from guaranteed. If such success is our goal, we should realize the scale of the challenge and buckle down now while we still have the resources to develop a costly new infrastructure. Otherwise, we get behind the curve, possibly facing unfamiliar chaos, loss of economic confidence, resource wars and the unforgiving https://dothemath.ucsd.edu/2011/10/the-energy-trap/. The other controlled option is to deliberately adjust our lives to require fewer resources, preferably abandoning the growth paradigm at the same time. Can we manage a calm, orderly exit? In either case, the first step is to agree we face very important challenges. Techno-optimism keeps us from even agreeing on *that*.

Original article https://dothemath.ucsd.edu/2012/02/the-alternative-energy-matrix/

The following though is a summary of graphics to provide energy literacy in understanding the challenges we face.

The Energy Picture In As Few Graphics As Feasible To Summarize The State of Affairs (please see https://www.slideshare.net/DanCloutier3/the-energy-picture-in-a-few-graphicspptx)

"Facts do not cease to exist because they are ignored."~ Aldous Huxley

"Here's to the crazy ones. The misfits. The rebels. The troublemakers. The round pegs in the square holes. The ones who see things differently. They're not fond of rules. And they have no respect for the status quo. You can quote them, disagree with them, glorify or vilify them. About the only thing you can't do is ignore them. Because they change things. They push the human race forward. And while some may see them as the crazy ones, we see genius. Because the people who are crazy enough to think they can change the world, are the ones who do."