Canada's Energy Future

Stored Energy Built This Northern Nation

Renewable Energy Will Allow it to Endure

John Meyer,
Canadians for a Sustainable Society,
Book: The Renewable Energy Transition, Realities for Canada and the World
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ISBN 978-3-030-29115-0

Context

- Canada's Energy Future is as much about the energy demands of living in an extreme climate as it is about the ability to produce energy.

- Efficiency may become almost as important as energy production.

Pre-Contact Population Density

Inuit - 1 person/700 sq km - 2000 people in 1.4 million sq km.

Greenland Viking - pop < 5,000

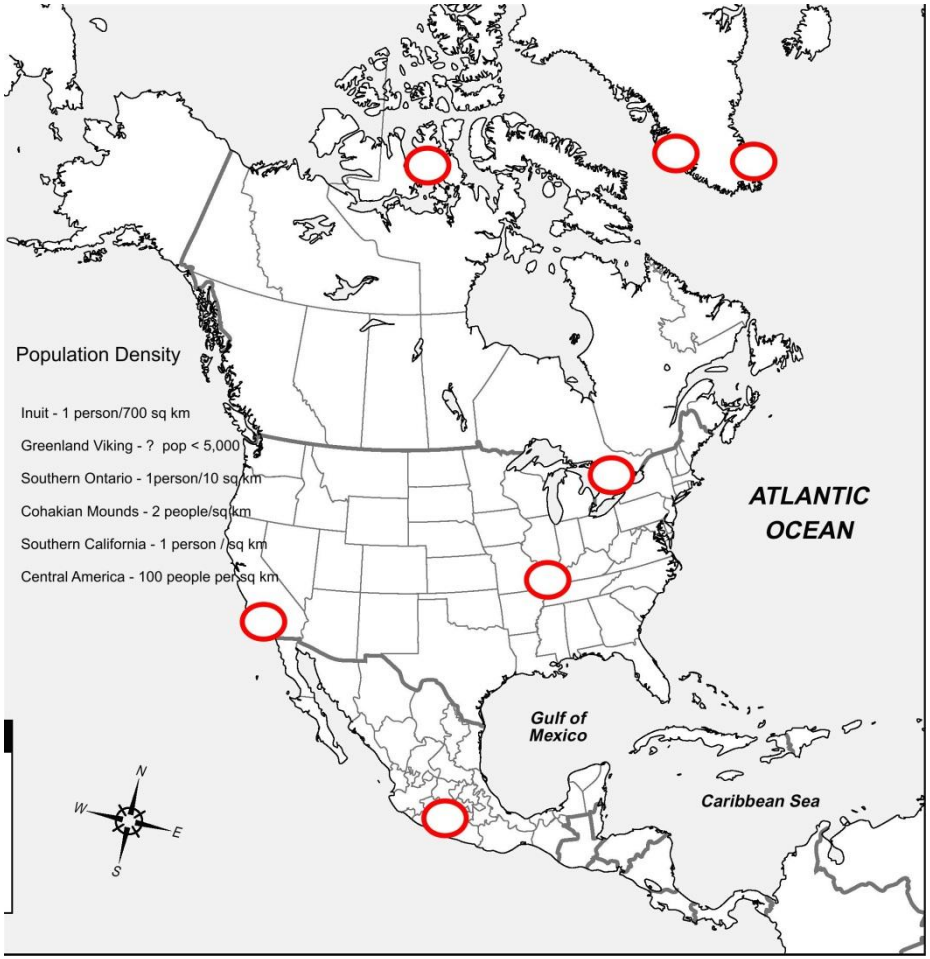
Southern Ontario – 1 person/10 sq km

Cohakian Mounds - 2 people/sq km

Southern California 1 person / sq km

Central America - 100 people per sq km

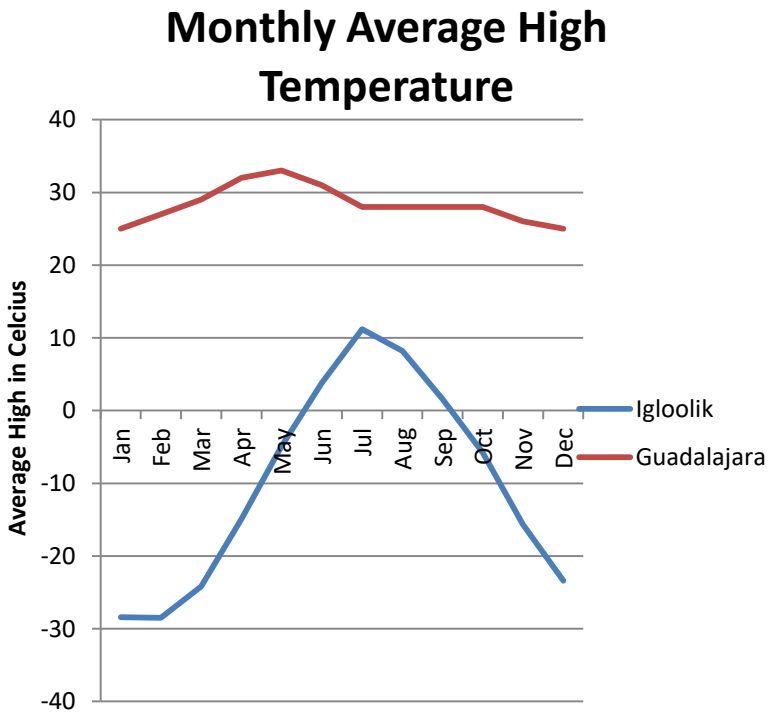
Europe of 1500 - 90 million people in 1 million sq km

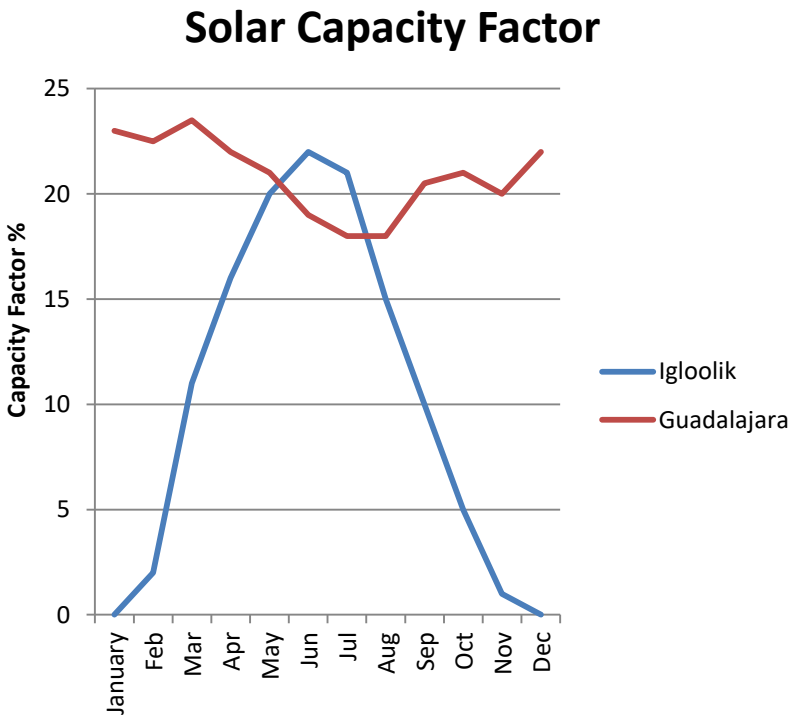


Population density (net energy proxy) utterly dependent on climate and resources at hand.

Most of Canada "empty" for a reason.
But it wasn't empty, it was as full as breeding humans could make it with their current access to energy.

Solar Capacity vs Energy Demand for Northern Regions





Without a strategy, the sustainability of a society is inversely proportional to its ability to grow.

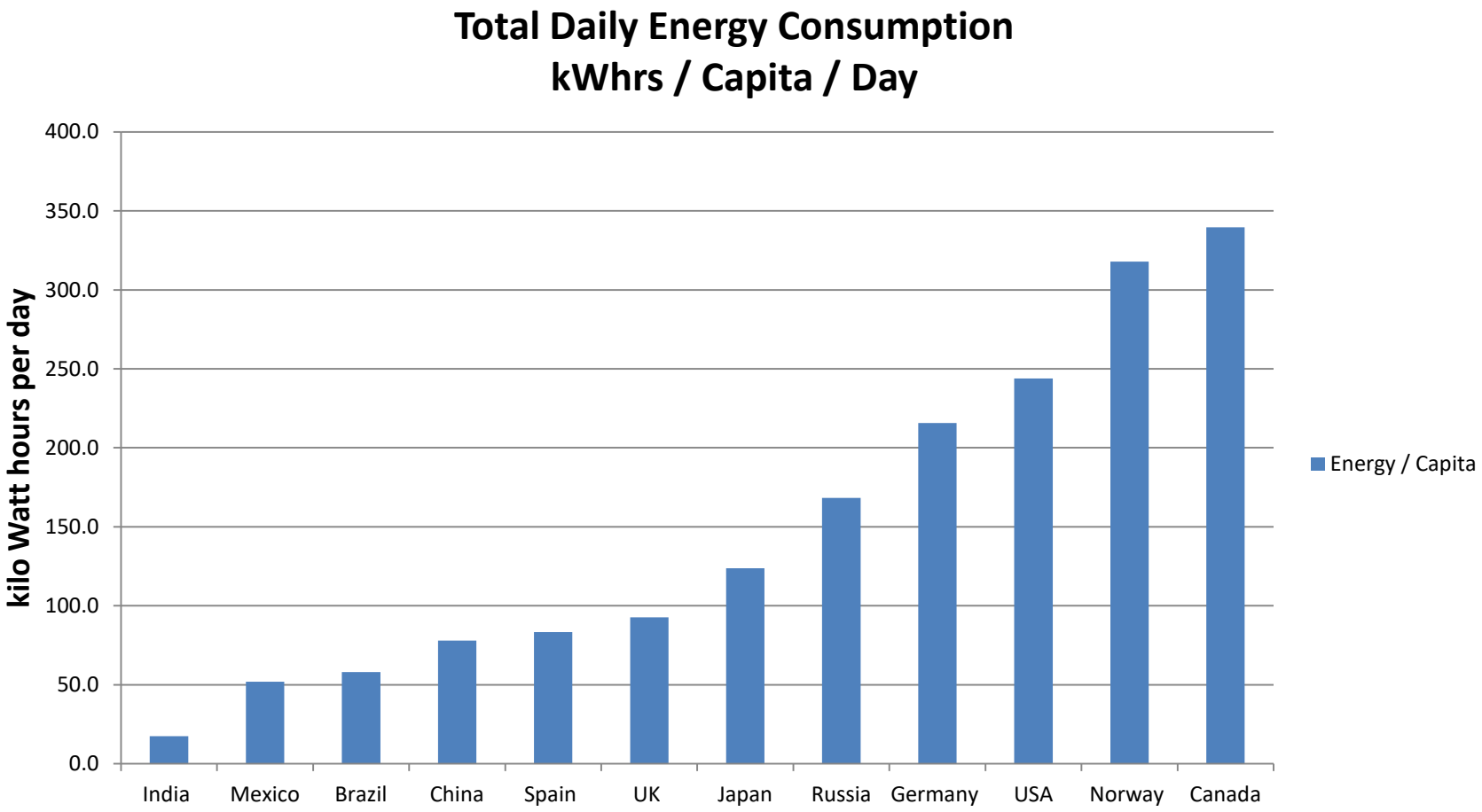
- Inuit society
  - 2000 people on a 1.4 million sq. km area
  - 5 million seals
  - Annual harvest ~20,000
  - Population never grows large enough to develop higher technology and destroy its environment

  Mayan society
  - Up to 100 people per sq km
  - Rich environment
  - Rapid population and technological growth
  - Rapid destruction of the environmental base and inevitable repeated societal collapse

Net Disposable Energy

- Final Resource Availability vs Critical Resource Demand
- If a society discovers a rich source of energy in a region with substantial available resources and a moderate climate, the standard of living can be quite high and population dense.
- Low energy availability, low grade resources plus extreme climate = low standard of living for a very limited number of people spread over a large area.
- In the future, energy will be less available and mineral ore grades will be lower.
- We need to know how much energy is required to deliver the basics of a cohesive society in Canada's biophysical reality.

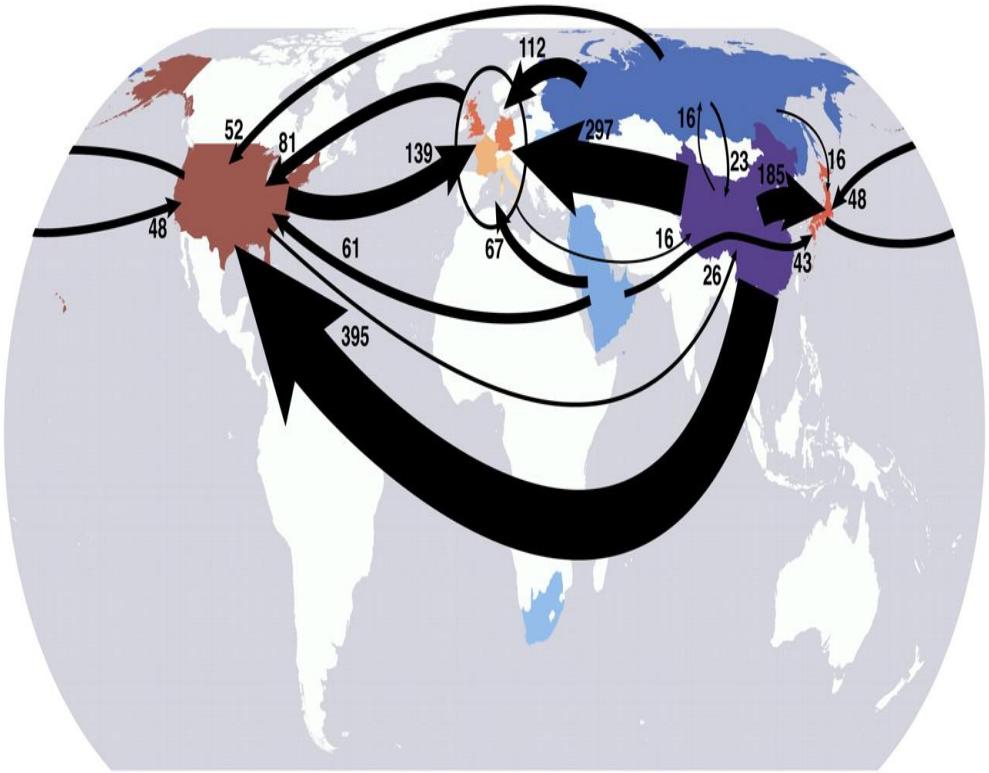
Need for Unified Energy Measure to represent daily per capita energy budget



Globalism is Largely Energy Export

Industrial Powers have been cheap energy (coal mostly) driven.

First Britain, then Germany and USA and now China.



This is the net carbon emissions embedded in trade, a good proxy for net fossil fuel export.

- China's coal reserves will last perhaps another 30 years.
- Their goal of achieving a moderately sophisticated society with technological parity and food, energy and manufacturing self-sufficiency has been achieved.
- When they are totally dependent on renewable energy will they still be interested in shipping the equivalent of 11kWh per capita per day out of the country?
- 11kWh per day per person is a large chunk of their daily energy budget.
- Implication: if Covid-19 didn`t make the case for repatriating manufacturing and research for you, perhaps the unlikeliness of China , or any nation, being able to maintain substantial net energy exports will .

The Small Problem of Seasonal Storage

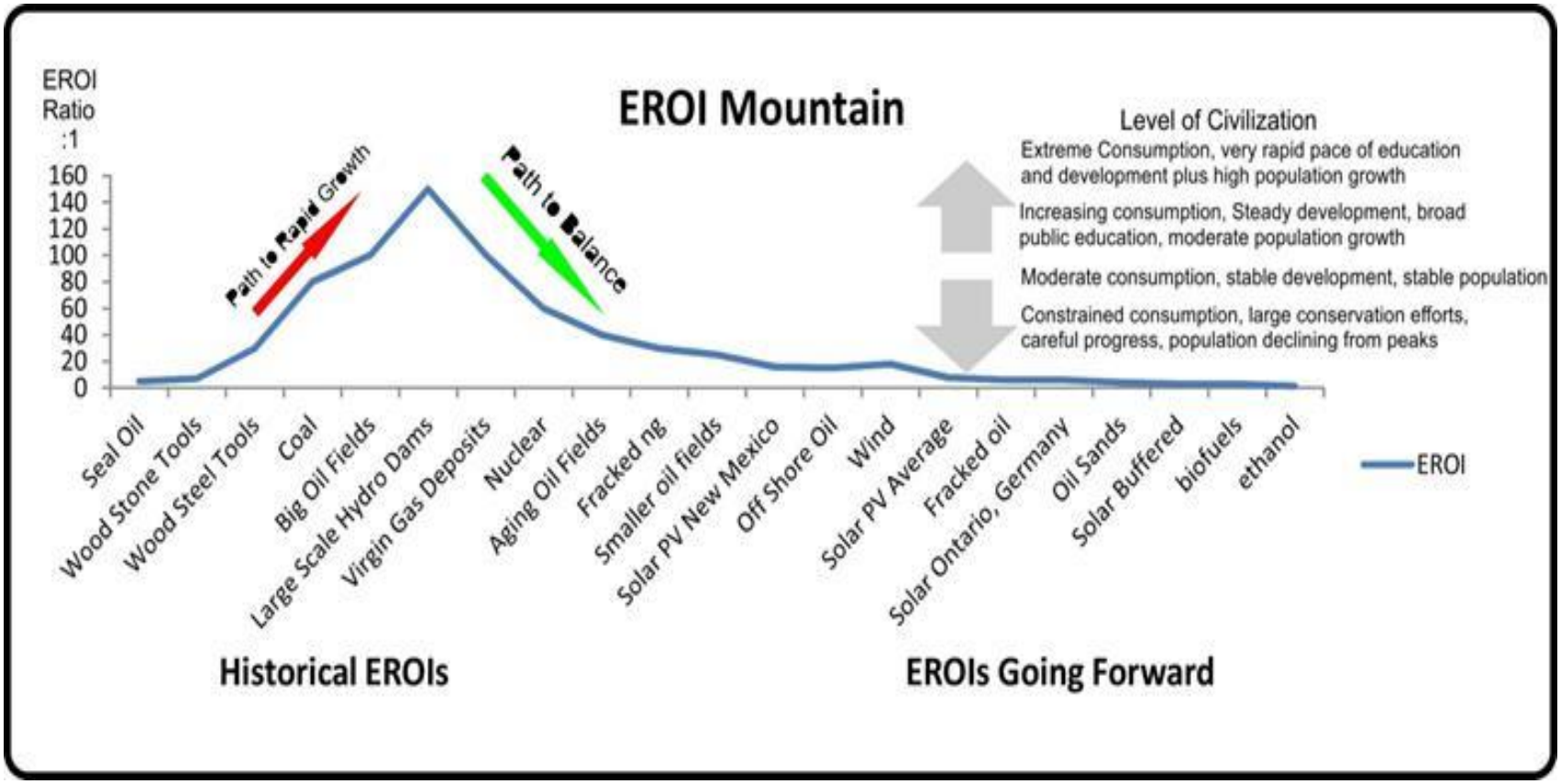
- Storage and Investment by Latitude per conventional house

	Annual Budget kWh	Storage Required Days	Storage Required Annual kWh	Size of Array Required kilo Watts	Storage	Array	Total
Igloolik	14600	120	4800	63.4	$ 4,080,000	$ 126,736	$ 4,206,736
Calgary	10950	90	2700	27.2	$ 2,295,000	$ 54,315	$ 2,349,315
Victoria	7300	60	1200	17.3	$ 1,020,000	$ 34,564	$ 1,054,564
St. John's	10950	90	2700	28.5	$ 2,295,000	$ 57,031	$ 2,352,031
Wilmington, NC	4380	4	48	3.2	$ 40,800	$ 6,337	$ 47,137
Guadalajara	1825	0.5	2.5	0.7	$ 2,125	$ 1,302	$ 3,427

EROI Issues

- Energy Returned on Energy Invested
- EROI for renewable energy stand alone systems
- EROI for R.E. systems with storage
- Limitations of solar and wind in Canada

EROI Mountain



* Declining EROI *
Will The COP of the Electrical Economy Ride to the Rescue?

Can Coefficient Of Performance of electrical heating systems and efficiency in transport systems offset the decline in EROI?

- Drake Landing - 30:1 COP?
- EV 80% lower energy consumption

- Effectively, EROI is the efficiency of the energy generation system and COP is the efficiency of the energy consumption system

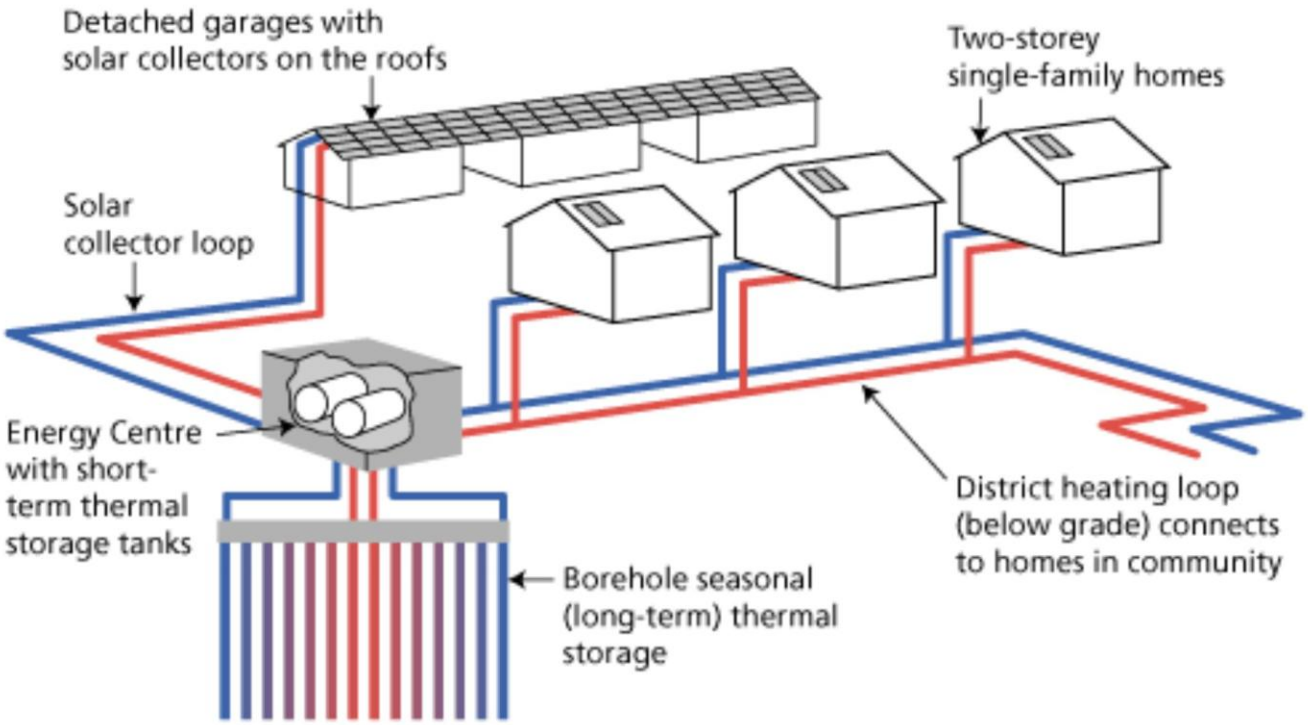
Electric Systems Benefits

over fossil fuels

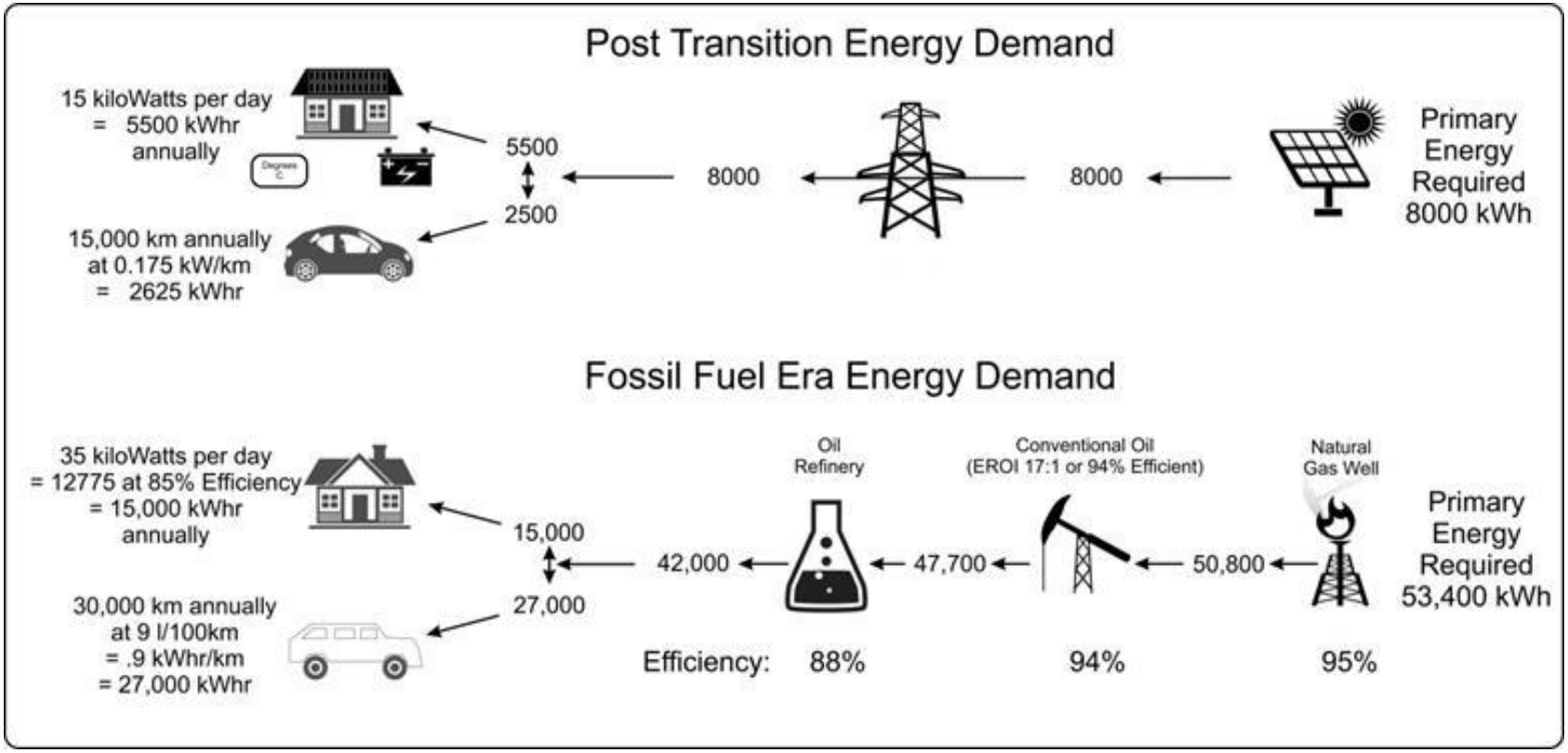
- Able to boost COP
- More efficient so less gross energy required
  - Internal Combustion Engine automobile might consume 10 litres per 100 km
    - 1 litre of gasoline = ~ 10kWh
    - = 100 kWh/100km or 1kWh per kilometer
  - An EV might consume = 0.2 kWh of electrical energy per kilometer or 20kWh / 100km
  - EV requires 20% of gross energy of Internal Combustion Engine (ICE) vehicle

Drake Landing Geothermal Storage

Art Hunter, Sweden

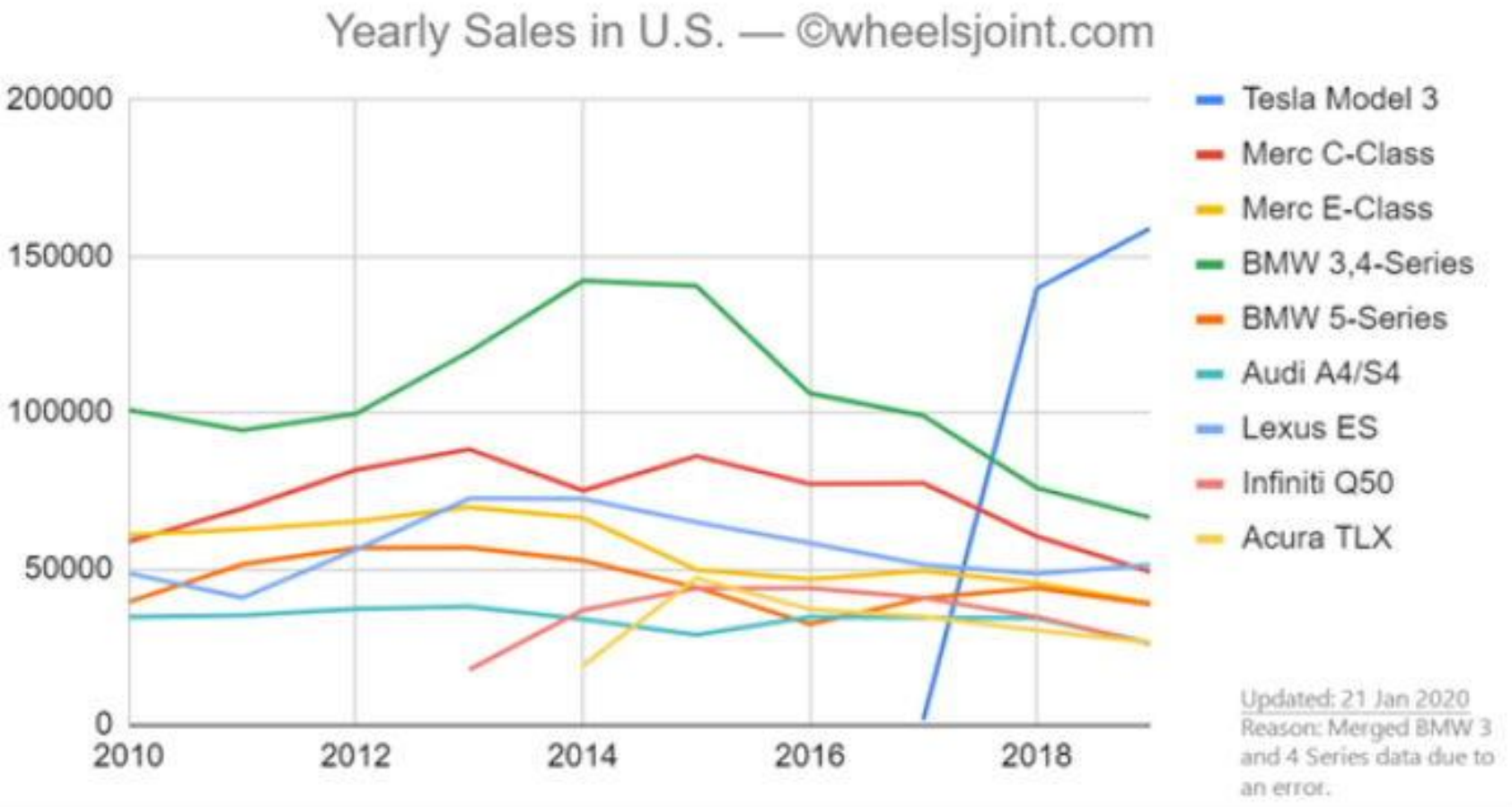


The Different Energy Consumption Levels of Fossil Fuel and Electrical Societies



Goodbye ICE!

(Drive an EV and see why)



Sweden vs Canada

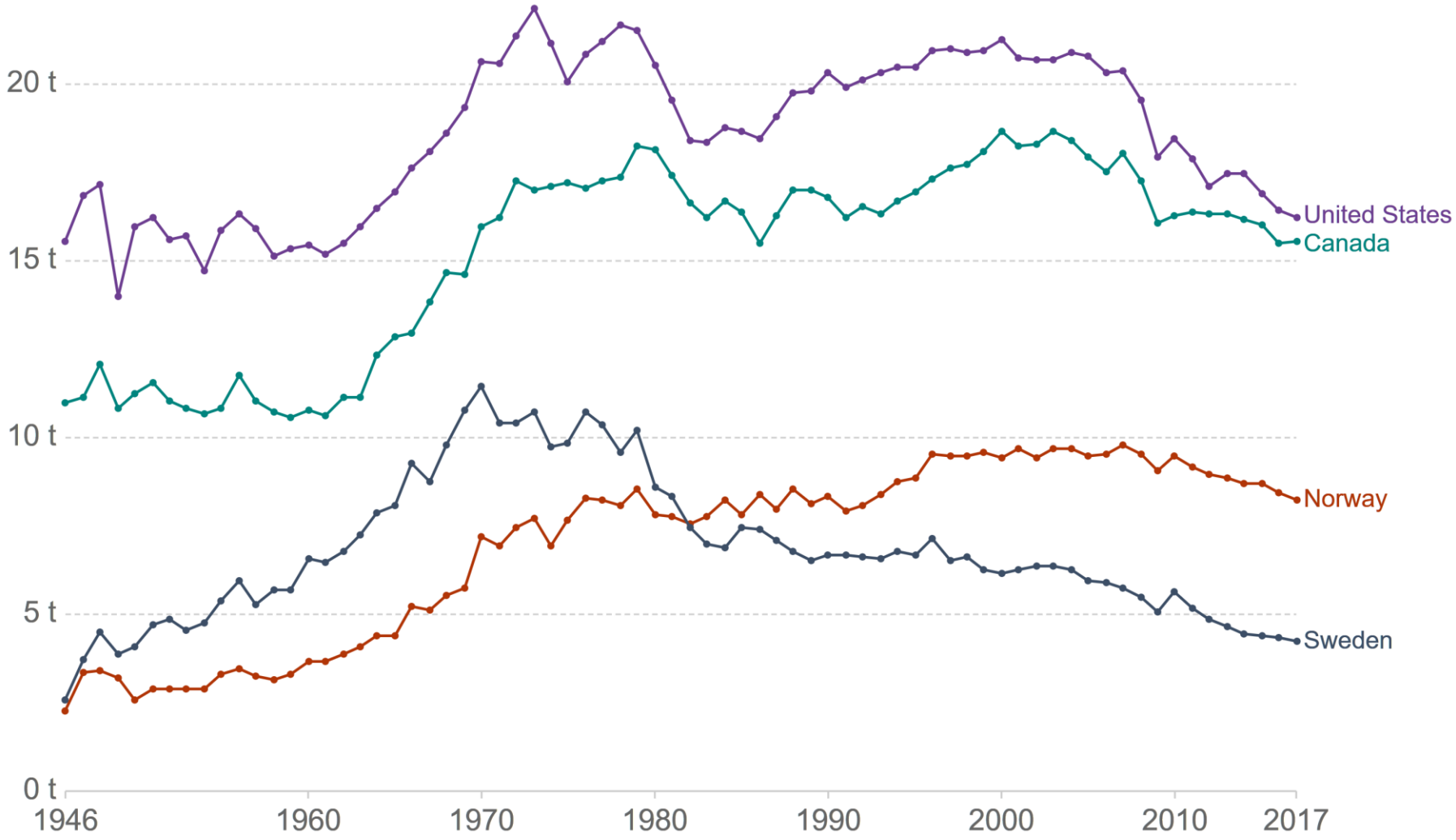
- Energy consumption per capita about 50%
- CO_2 emissions per capita about 30%

- Reasons for difference in emissions
  - Sweden more highly electrified – further along the renewable trail
  - Many more geothermal and district heating systems
  - More public transport (body heat from passengers routed to office buildings)
  - Smaller cars, shorter distances
  - Not a net energy or food exporter
  - Not a producer of fossil fuels

Per capita CO_2 emissions

Average carbon dioxide (CO_2) emissions per capita measured in tonnes per year. This measures CO_2 emissions from fossil fuels and cement production only – land use change is not included.

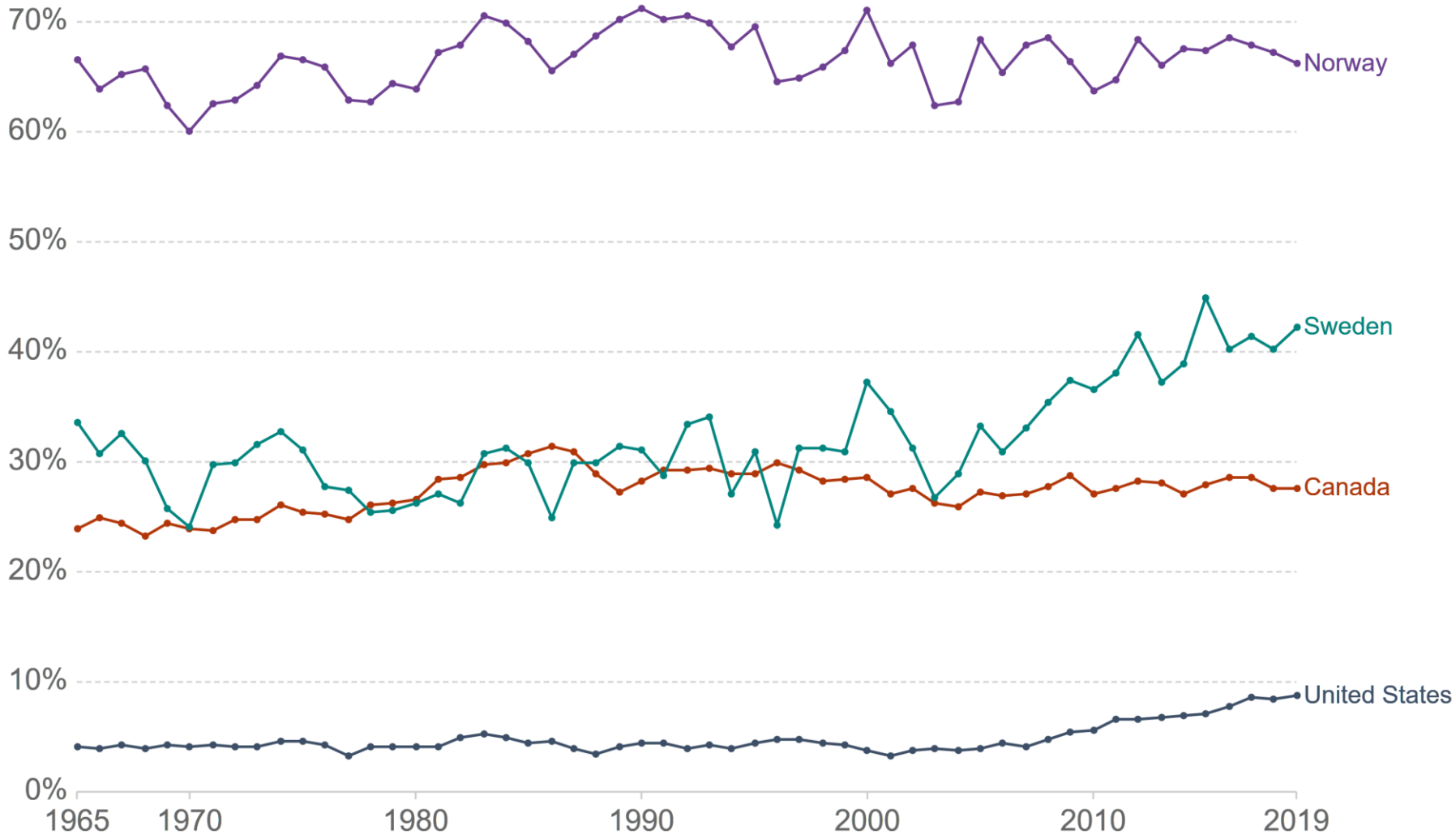
Our World in Data



Source: OWID based on CDIAC; Global Carbon Project; Gapminder & UN
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

Share of primary energy from renewable sources

Renewable energy sources includes hydropower, solar, wind, geothermal, bioenergy, wave and tidal. It does not include traditional biofuels, which can be a key energy source especially in lower-income settings.



Source: Our World in Data based on BP Statistical Review of World Energy (2020)

OurWorldInData.org/energy • CC BY

Note: Primary energy is calculated using the 'substitution method' which takes account of the inefficiencies energy production from fossil fuels.

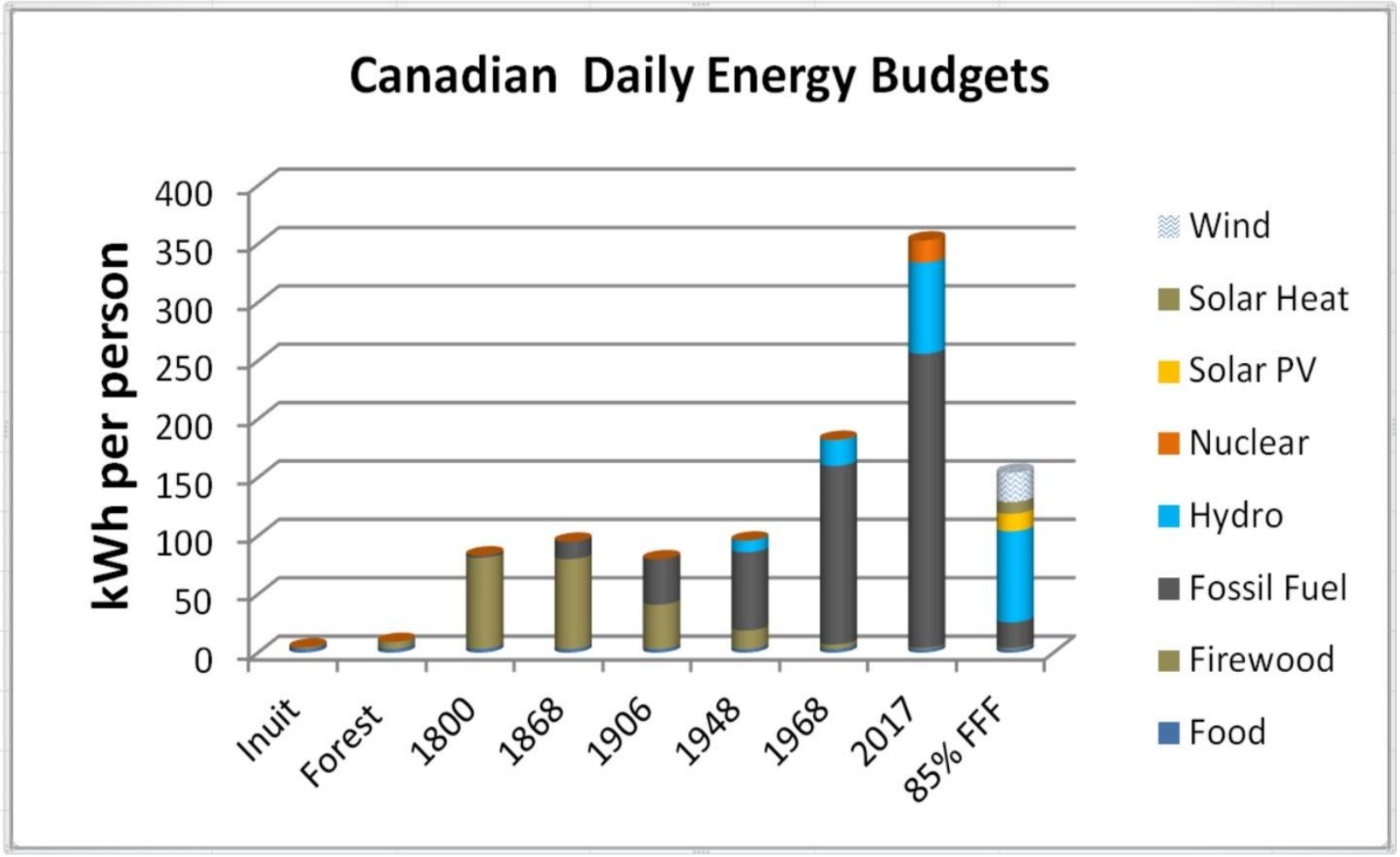
High Grade vs Low Grade Energy

- Electricity is high grade energy and heat is low grade energy
  - Electricity from solar can be generated at under 20% efficiency
  - Heat from solar can be generated at over 40% efficiency
  - Electricity storage requires extremely expensive batteries which can be 90% efficient
  - Geothermal heat storage can be done for under 1% of the cost of electrical batteries and may approach 50% efficiency
  - High grade energy is scarce and expensive, low grade energy is cheap and abundant
- Use high grade energy for high grade uses
  - Transport
  - Mechanical, Industrial
  - Lighting, appliances

Geothermal (earth's stable heat mass) is both abundant and close at foot. Earth is one giant heat battery.

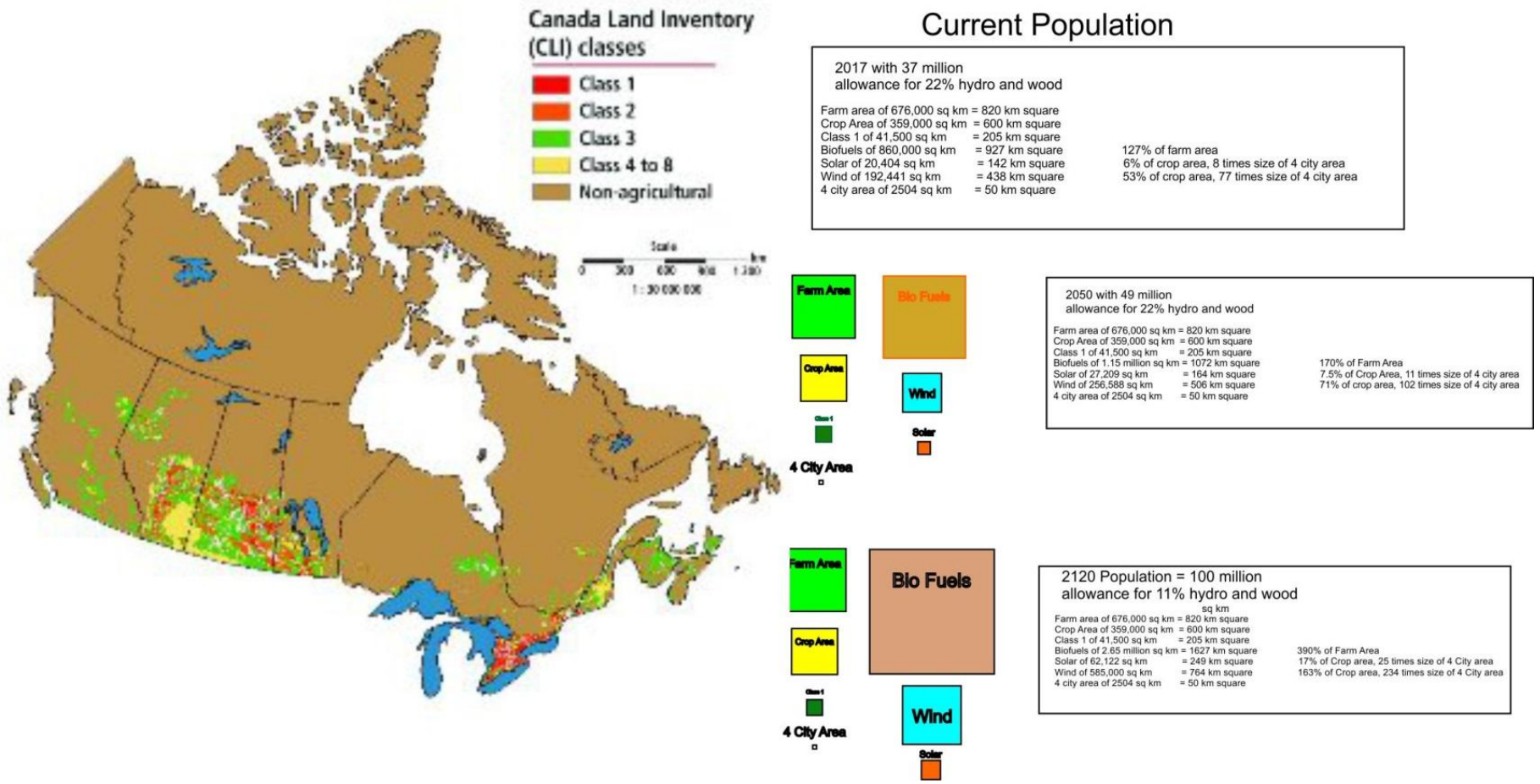
Use only low grade energy for heat.

Energy Consumption History



Renewable Infrastructure

Storage and Overbuild not included

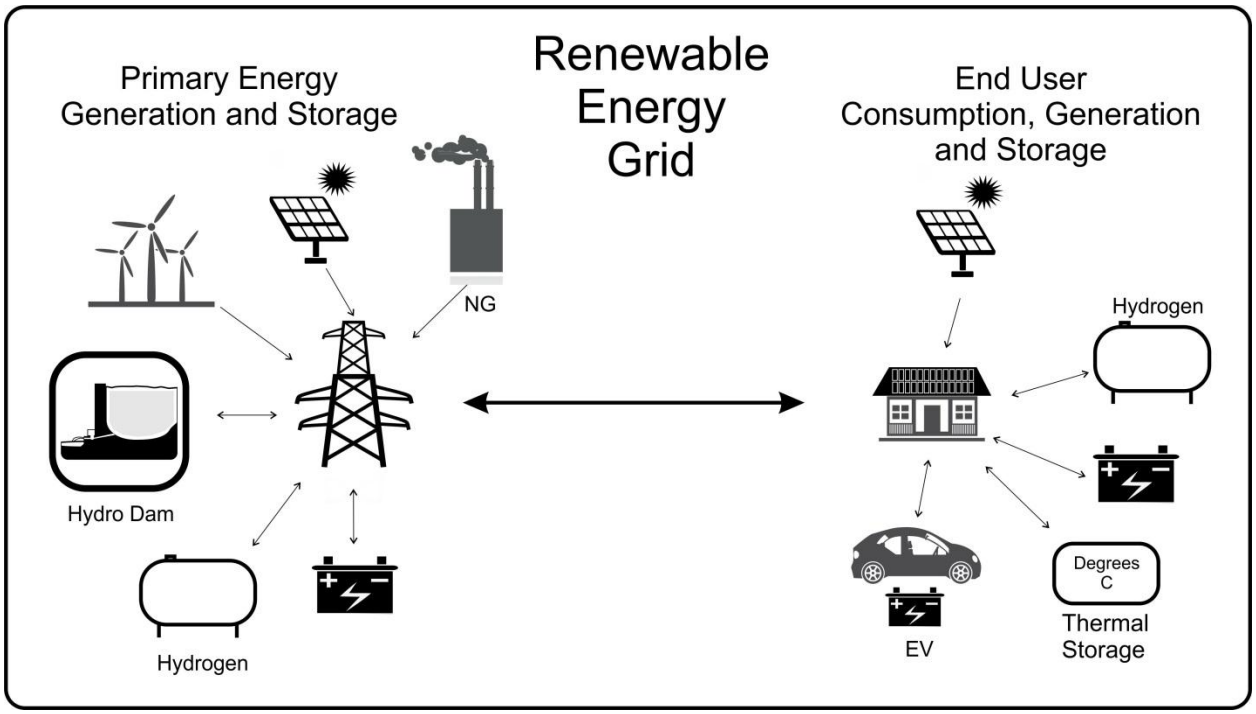


The transition to renewable energy will be a huge challenge with the population we currently have. Growth in either consumption levels or population will derail this process.

The Grid as a Living Organism

A much richer investment environment for large and small investors.

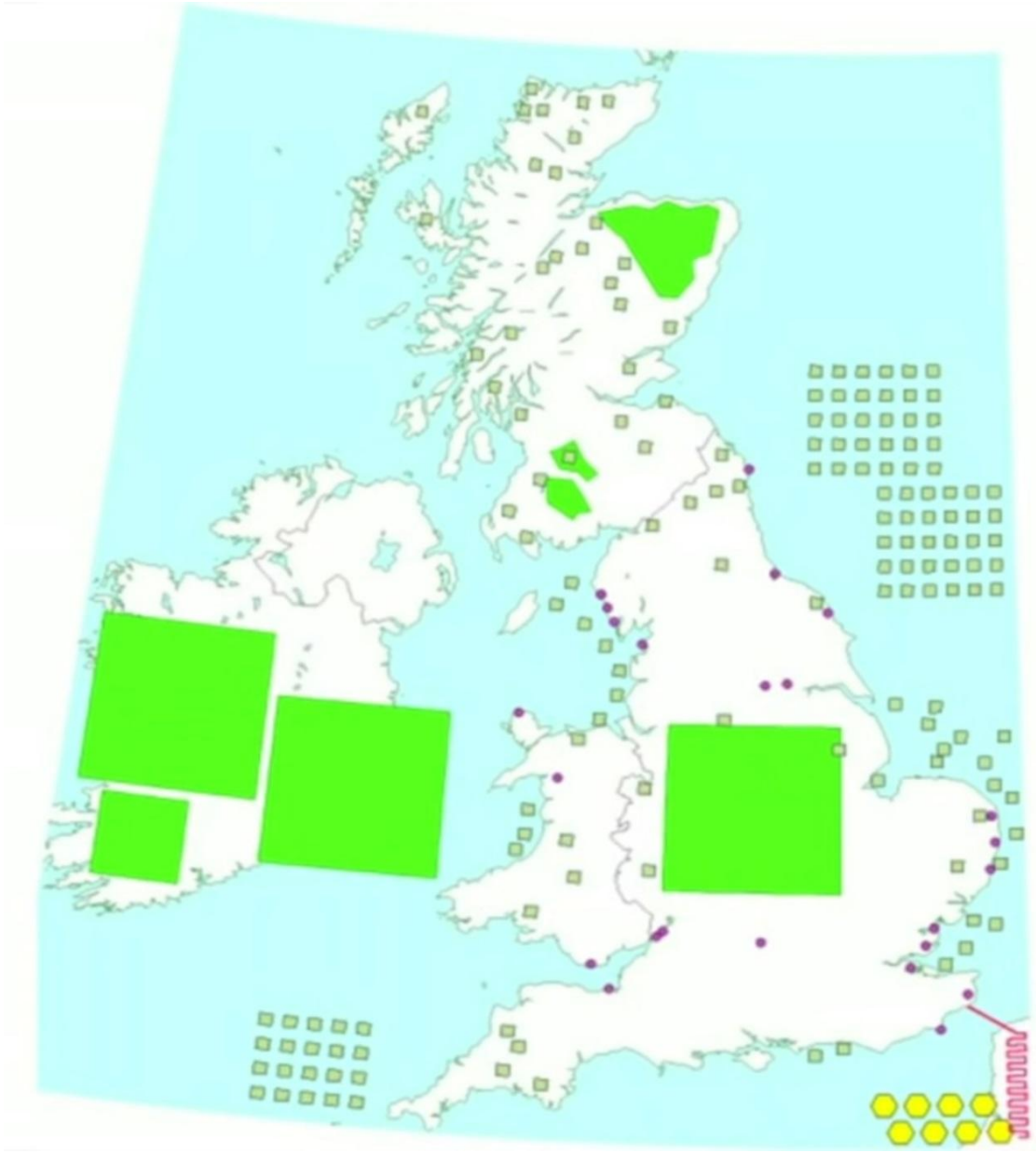
Individuals can much better control their own level of resilience and the stability of their energy costs.



The Transition Needs Aggressive Building Standards

House on the right consumes ~ 6,000 kW annually. With a 10kW PV array producing 12,000 kWh annually, it would produce enough spare energy to power an EV for 20,000 to 30,000 kilometers annually.

Cost of retrofitting houses on left would start with $80,000 to $100,000 (??) roof rebuilds.



Wind:
16 kWh/d/p

Nuclear:
16 kWh/d/p

Biomass:
16 kWh/d/p

Solar in deserts:
16 kWh/d/p

David MacKay
TED Talk “A Reality Check on Renewables”
www.withouthotair.com

Inevitable Subjects

- Hydrogen
  - Expensive storage
  - Very lossey ~ 30% round trip efficiency, membrane consumption?
  - Difficult to work with, high pressure, corrosive and slippery
  - High recycleability of tanks if stainless steel
  - Nearly unlimited scale – salt caverns etc.
- Nuclear
  - Stepping stone from fossil fuels to renewables

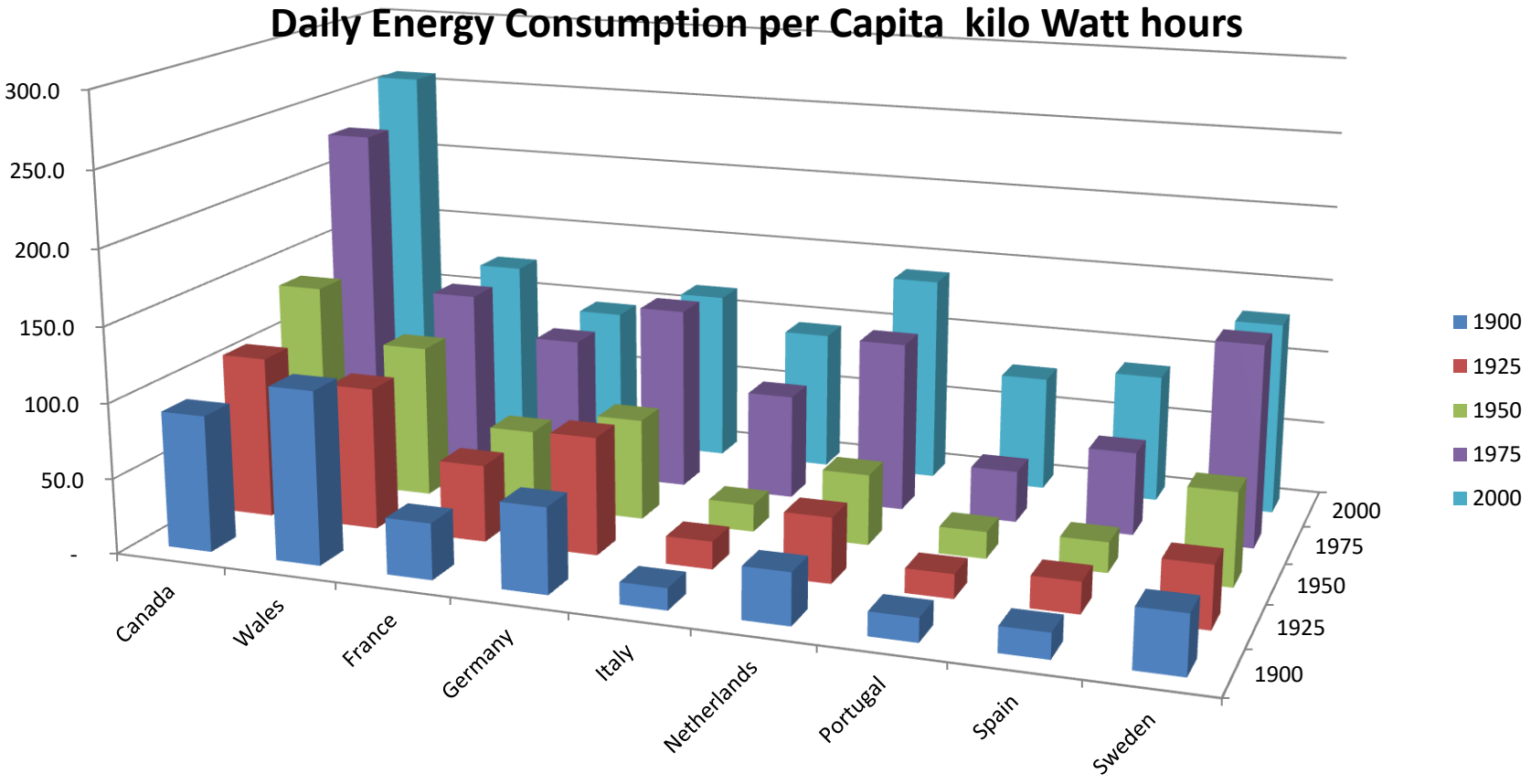
The Perfect Energy Generator /Source

(Dilithium crystals)

The little black omnipotent box with unlimited clean power.

Can we put a huge amount of power (heat) into the biosphere?

Comparative Energy Consumption in the 20th Century



Teach Your Children

- Every energy user from householders to businesses to government needs to understand how much energy they are using and for which purposes. They need to understand the type of energy they are using and the carbon emissions generated by them.

- We need to measure energy in one metric which will almost certainly be kilo Watt hours. Knowing how much electricity you use is as easy as reading your monthly bill or, much better, going on-line and getting daily readouts. You can see consumption in real time in your EV. But people use different types of energy and for home owners, natural gas is likely the main heat provider in most homes.

- Natural gas costs are low compared to electricity and that misleads many to believe they aren't using much energy. In fact, once you convert natural gas from cubic meters or cubic feet to kWh, a very different story emerges. In Ontario, a dollar of natural gas buys about 5 times as much energy as a dollar of electricity. So if your annual usage of electricity is say, $1,000 or 5,000 kWh of electricity and $1,000 of natural gas, your real total energy consumption is closer to 30,000 kWh - 5,000kWh of electricity and 25,000kWh of ng. The carbon emissions from natural gas - still the cleanest of the fossil fuels - are much higher than for electricity in Ontario as the majority is generated by nuclear and hydro.

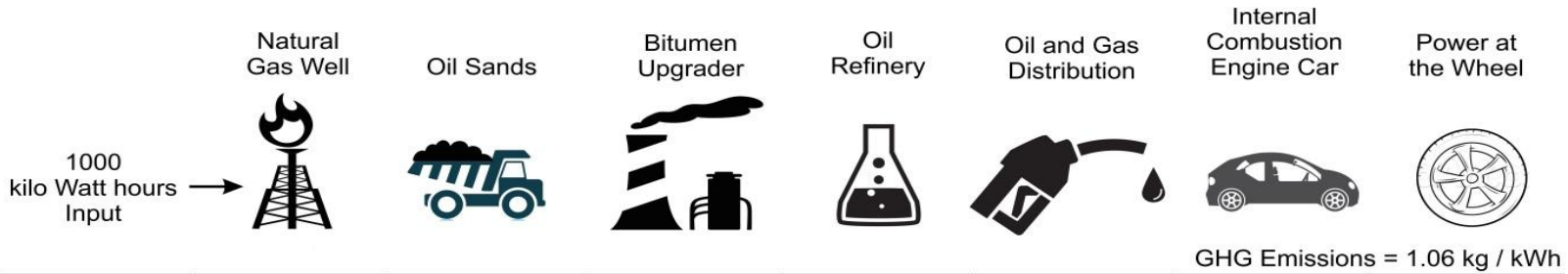
- Ditto for an automobile. There is about 10 kWh of energy in a litre of gasoline and if your car uses 10 litres to go 100km, then you've consumed 100 kWh of energy. An electric car typically uses 1/5th of a kWh to go 1 km so would use 20kWh to go 100km, a consumption level 80% lower than the internal combustion car.

- Carbon Calculator http://www.gbbr.ca/carbon-calculator

- This is a great home-school and in-school project for all ages of students.

Energy and Carbon
EV vs ICE

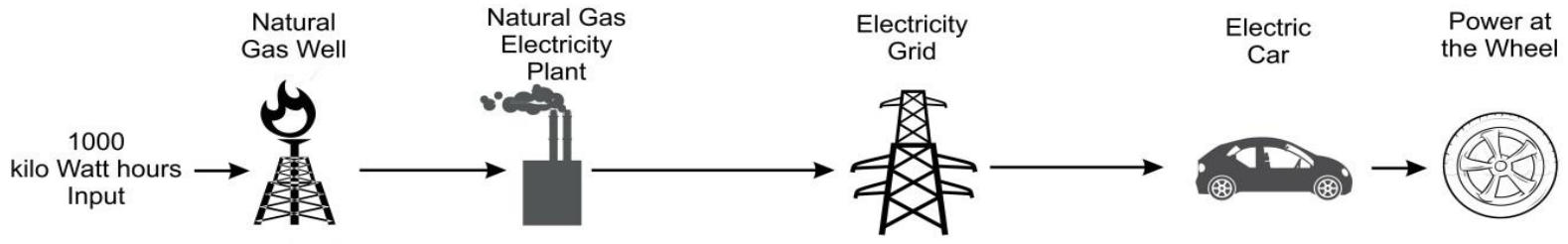
Oil Sands - Internal Combustion Automobile Lifecycle



GHG Emissions = 1.06 kg / kWh

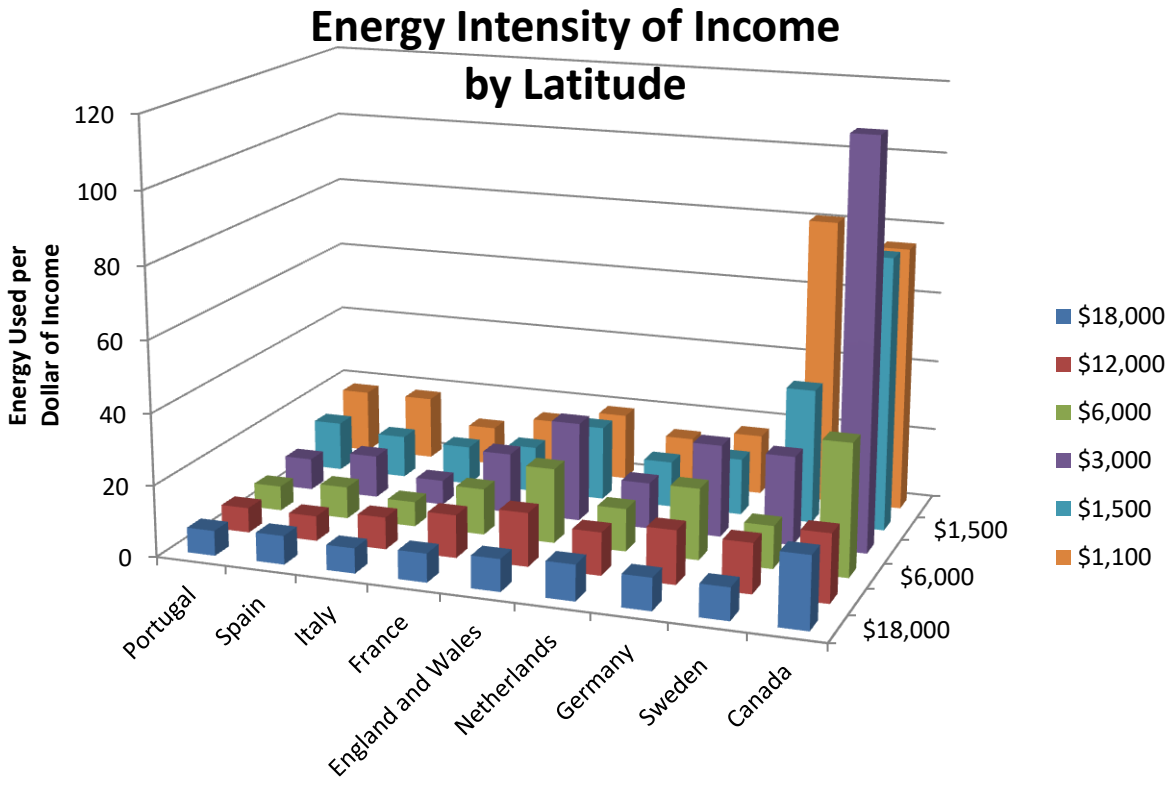
Process Efficiency	95%	72%	88%	88%	93%	35%	-
Energy Remaining kWh	950	3325	2927	2575	2394	-	838

Natural Gas - Electric Vehicle Lifecycle



GHG Emissions = 0.18kg /kWh

Process Efficiency	95%	70%	94%	95%	-
Energy Remaining kWh	950	665	625	-	594



Energy Equality - Richard W. Unger, as well as energy consumption history slide "Energy Consumption in Canada in the 19th and 20th Centuries"

Social coherence or iron fist, either way social order is required for a successful transition of this magnitude.

What to Do

The Stepping Stones to Renewable Energy and a Sustainable Society

- Start measuring energy in a single unified metric and for every home and business and express in kWh per day budgets.
- Stop population growth and migration to northern countries – allow population levels to decline, Canada target may be 20 million.
- Electrify the ground fleet as rapidly as possible
- Wind down the oil sands and maintain only a small capacity for essential fossil fuel applications
- Build natural gas generating plants with their quick reaction times to allow maximum penetration of renewables
- Build universal building access to geothermal heat and storage
- Re-build manufacturing base for a broad range of goods, and specifically for all pieces of essential renewable energy infrastructure, food production, transport and medical supplies.

Prepared for Change?

- Covid-19 was something we should have been prepared for as we've had pandemics before and protocols were well established.
- BUT – our public didn't know what to do, our experts stumbled and our leaders bumbled.
  - Canada's Chief Health Officer – masks don't work and borders won't stop a pandemic.
  - The USA's CDC testing process failed, then Trump worked his magic.
  - The UK's Boris "Let me shake your hand" Johnson glad handed his way through a covid ward almost killing himself and his pregnant fiancee. Public policy was similarly bungled.
  - Sweden was prepared (except for nursing homes) and did something well-considered but very different from most countries.
- With micro-grids and all-inclusive energy consumption stats, many people will know what to do as the energy / climate transition pitches knuckle balls.
- Resilience depends on millions of people being prepared and making the right decisions. Microgrids and EVs will establish a broad based relationship with energy that will make it easier for leadership to maintain stability.
- Clear-eyed, informed hope is the best motivator.

Distortions and Misleading Measurement Systems

- Determining the long term viability of Renewable Energy systems

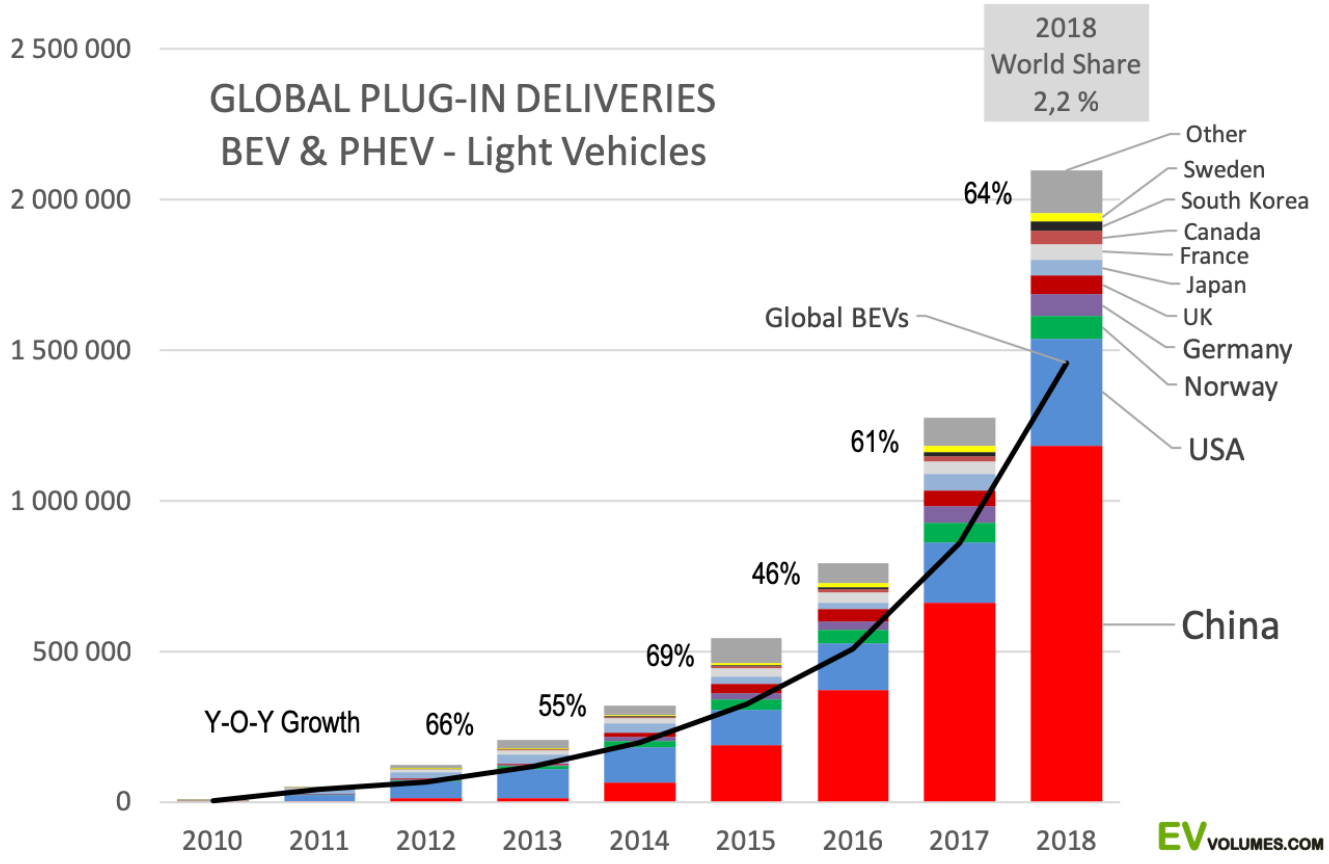
- Fossil fuel
  - RE now made with Chinese coal builds RE systems but can RE systems be built and maintained solely with RE in Canada?
- Dollar metrics are fatally misleading – use real biophysical units
  - Dollars can distort anything. They can be printed and injected into any process in myriad ways to make it look viable.
    - Ethanol
    - Oil sands
    - Any project from which the powerful can profit
- To maintain efficiency and maximize long term investment, energy prices must be stable ie rising gradually and predictably.
- Hidden subsidies unwind slowly
  - We won't fully understand or be able to quantify the viability of full renewable energy systems until we are well along in the transition process.

Policy Priorities

The fastest, best ways to transition off fossil fuels

- Strategy, models, good data, real physical units, rapid learning.
- Put science and human and environmental welfare back at the national policy table and push finance and development back to their proper supporting roles.
- Abandon population growth and the energetic and environmental idiocy of “populate the north”.
- EVs – easiest, fastest, biggest payoff, cheapest.
- Get young hands and minds working on real systems with data collection and open source control programs. Living labs for every school!
- Prioritize geothermal storage, district heating, building standards to include energy harvesting and storage requirements.
- Landlord/tenant/condo coordination and standards to drive upgrading.

EV Adoption

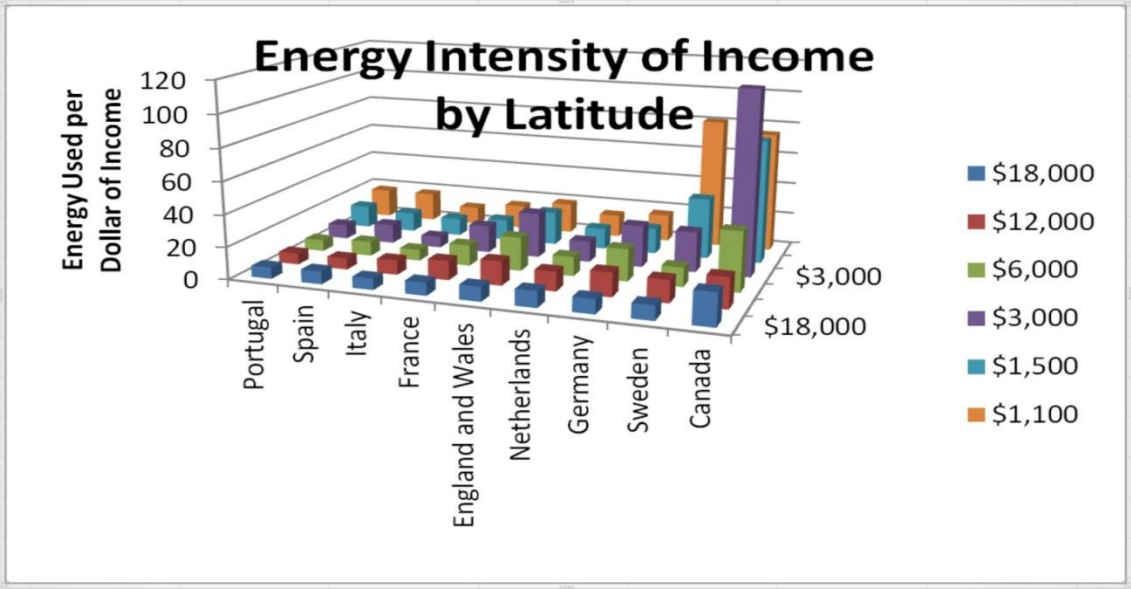

GLOBAL PLUG-IN DELIVERIES
BEV & PHEV - Light Vehicles
2018
World Share
2,2 %
2 500 000
2 000 000
1 500 000
1 000 000
500 000
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
Y-O-Y Growth
66%
55%
69%
46%
61%
64%
Global BEVs
Other
Sweden
South Korea
Canada
France
Japan
UK
Germany
Norway
USA
China
EVVOLUMES.COM

EVs are Critical

- Evs are the lowest hanging fruit
  - Greatest carbon emission reduction for lowest cost (> 30% ghg reduction)
  - Painless conversion from ICE to EV
  - Low cost
  - Strategic – no need for eastern pipeline if near total EV conversion within 30 years
  - Need road tax built into annual license instead of fuel

Social Stability Critical

- Transition to renewable/electrical is a huge transition.
- Can only be achieved by avoiding crushing lower and middle income groups
- The longer this process takes, the smoother it can be. ie start now.



Population Math

- Doubling Time Rule is *70/rate of growth*
- Rule of 10 Doublings
  - *double 10 times = 1000 times*
- Canadian population with 1% immigration
  - 100 million by 2120
  - 200 million by 2200
  - 37 billion by 2700

Which Plan Will Succeed in Reducing GHG Emissions?

- Canada – tripling population by 2120 and growing.
- Continued consumption growth.
- Narrow, growth based economy on construction, resource extraction and finance (asset inflation & wealth transfers).

- China – slight population decline by 2050, significant by 2100 to under 1 billion?
- Broad based, high tech economy with high capacity for wind and solar fabrication.
- Target is for “moderately sophisticated society”.

Growth

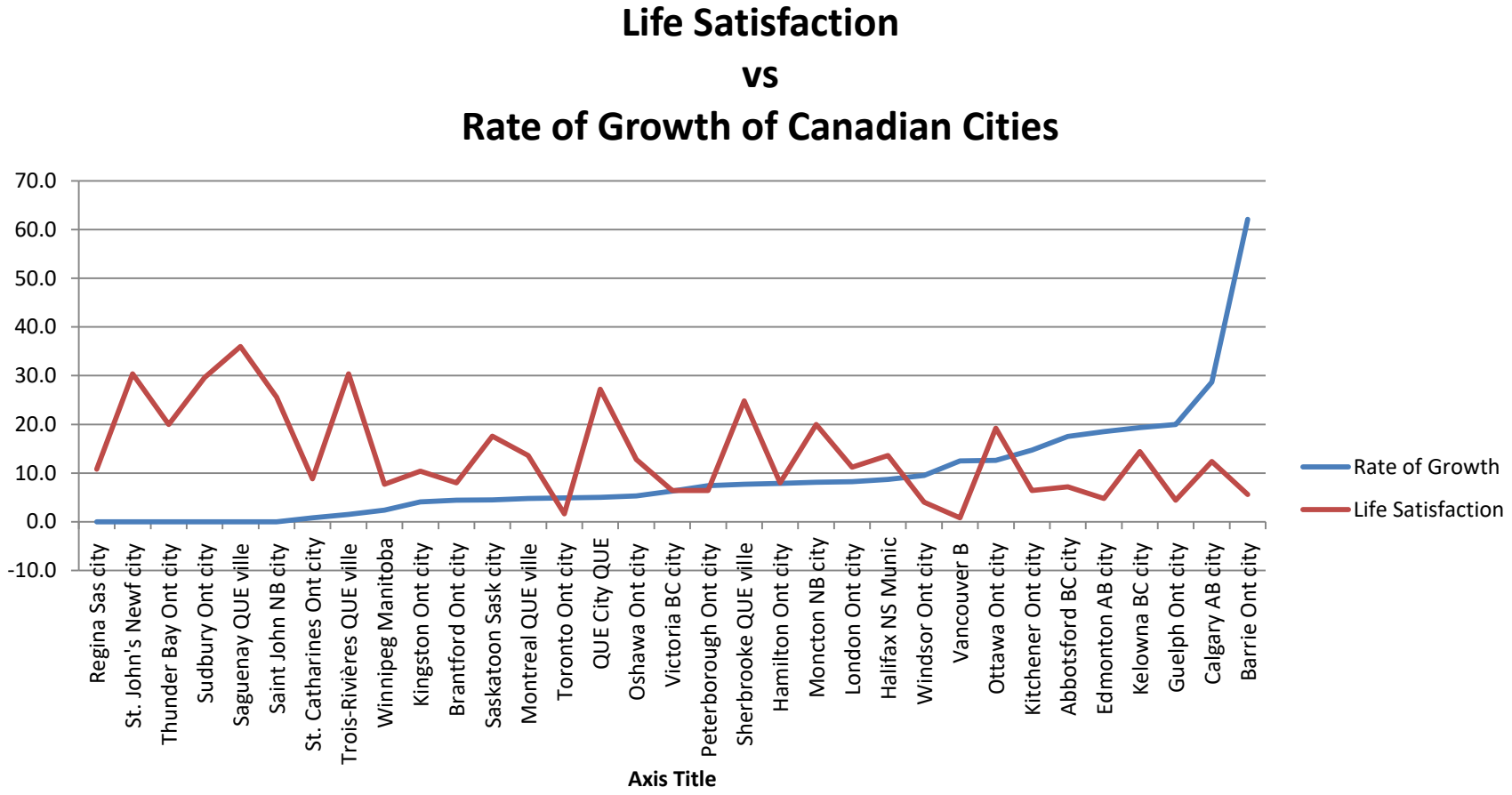
Why?

- What we are doing now is unsustainable, more of the same is not possible in the long term.
- Population growth paves over some of the best farmland remaining in the world.
- No net benefit to the individual.
  - Mostly negative impacts, lowers per capita resource base.
- Huge negative impacts for the land.
- Better to develop human potential.

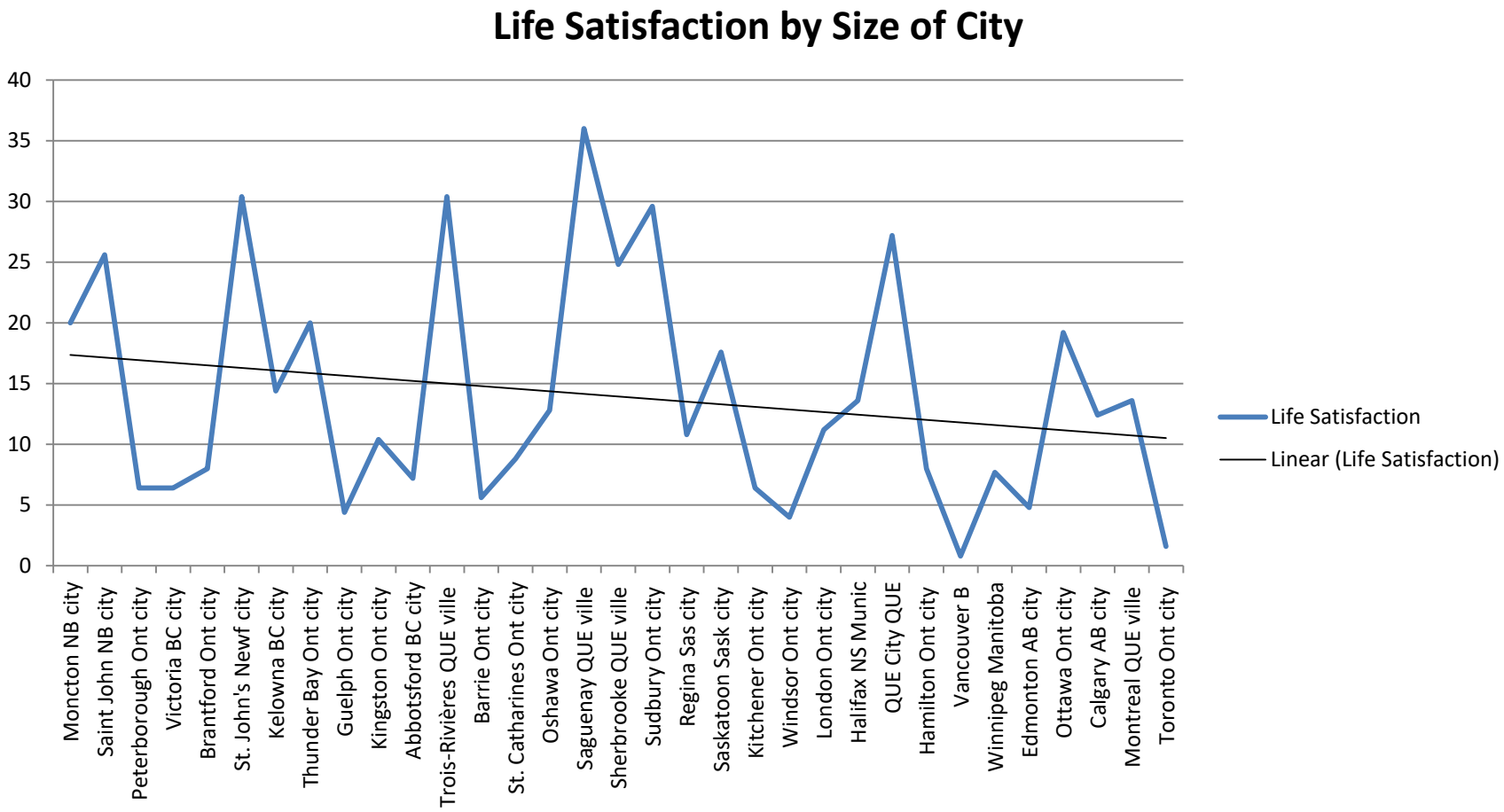
What has Growth done for you Lately?

- Yes, the Canadian economy has been the fastest growing in the OECD for the past 50 years but how have the citizens fared?
  - equality level has fallen from 2nd best in world to #23.
  - Per capita resources has fallen.
  - Legacy costs of environmental damage has risen.
  - Social safety net has weakened.
  - Increasing deficits and debt are structurally locked in.
  - Quality of life has fallen.
  - Debt increased
  - Cost of housing increased
  - Gig economy – insecure young people

Growth is not Satisfying

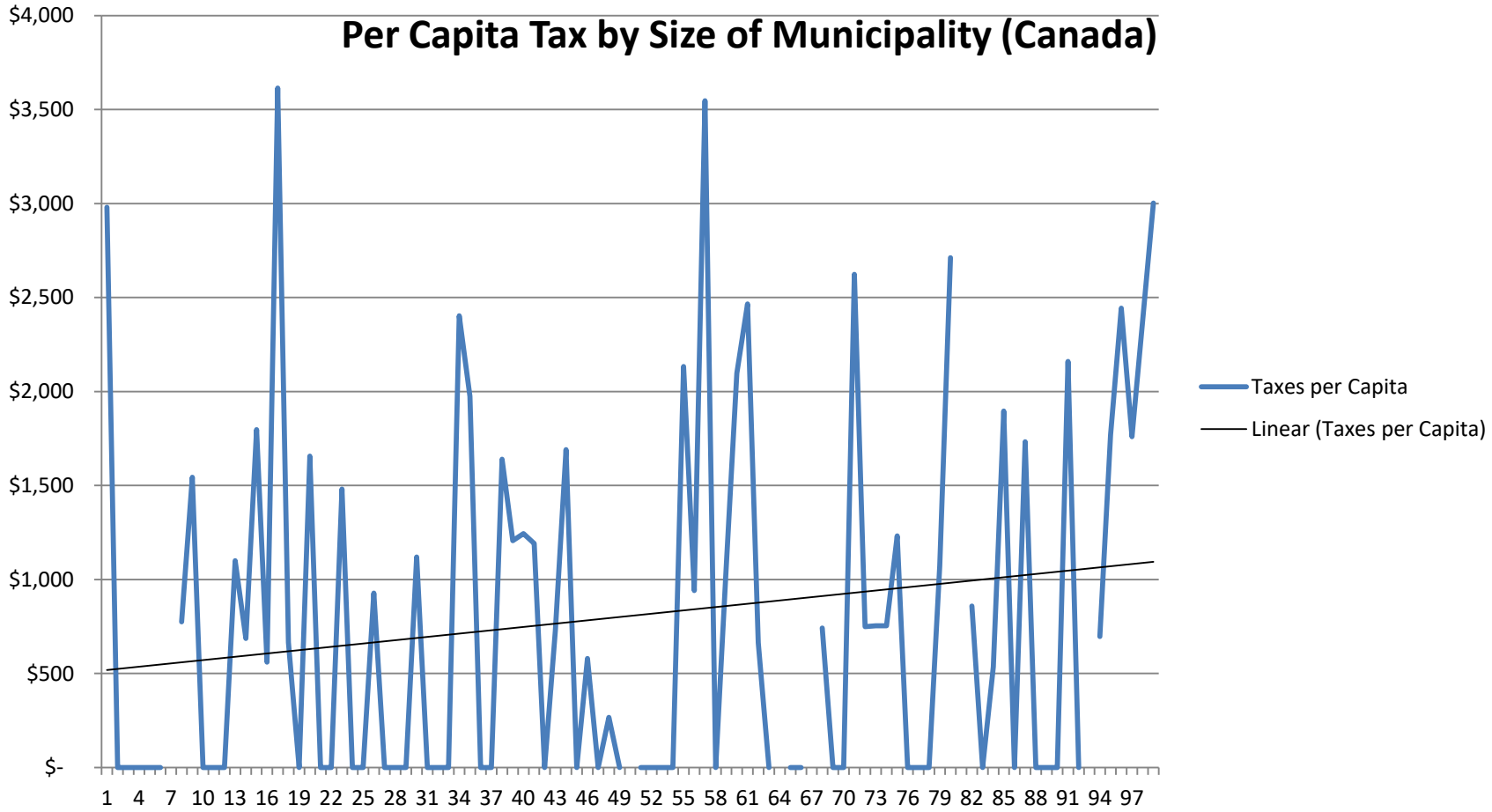


Bigger is not Happier



Bigger Means More Expensive

maybe



Follow the Money

- Who profits from growth?
  - Developers
  - Cheap labour employers
  - Debt mongers
  - Media corporations

  = Political donations and positive coverage

Conflicts of Interest

	Growth Forever Lobby Interest	**Public Interest**
Economic Measurement	GDP growth –continuously higher dollar flows	Higher or stable incomes per capita. Size of economy is unimportant
Environmental Requirement	Environmental considerations are obstacles – costs which do nothing to enhance the bottom line	Environment is critical to health, quality of life and future prospects of generations to come.
Resource Priority	Exploit as quickly as possible	Maintain high ratio of resources per capita for the long term
Time Reference	Quarterly report, annual bonus, maximum 5 years view	3 generation view for most families, nation needs 7+ generation view
Equality	Conflicts with need for cheap labour	Higher levels of equality means higher quality of life and a stronger social safety net
Employment	Needs short term cheap labour, low investment	Wants higher incomes, higher productivity, job security
Fiscal Balance	Irrelevant mostly but tightly managed budgets mean fewer subsidies	Fiscal balance critical for health of social safety net and stability

Conflict of Interests 2

Investment	Have the government (tax payer) make the investments in infrastructure necessary for rapid growth	Maximum investment for highest education and productivity and social services
Debt	Public assumes debt for rapid development which lasts far longer than any income from the development	Debt is minimized by stable development projects which pay their own way
Infrastructure	Minimum needed for projects to proceed	Full spectrum of infrastructure needed to support communities and their long term stability including maintenance of the infrastructure
Scientific Integrity	Facts as required to support the project only right now.	Full spectrum of information to provide perspective on all aspects of public interests over the long term.
National Goals	Growth, more, business as usual	Quality of life, stability, progress for the individual, the family, the community and the nation
Transparency	Corruption can only take place in an environment of low levels of information and high levels of confusion	Full information and clear national goals are critical to transparency and public policy in the national interest

Social Stability Critical

- Transitioning to renewables challenges social stability. Real costs go up. Lower income groups are more resource and energy sensitive than the wealthy.
- Syria - large sudden food and fuel cost increases
- France - housing cost and fuel tax
- Brexit - housing costs, low wages
- Ontario - hydro cost, housing costs, low wages
- French Revolution storming of the Bastille on July 14, 1789 the day grain prices reached their highest level in history.

- Real costs must be paid by the user. Subsidies mask real costs and inevitably cause shocks when eliminated.
- We need to incentivize energy generation and conservation but must not subsidize energy consumption.

Plan Now

- Better planning now means lower costs later.
- An early start means fewer big shocks down the road.
- Resilience is expensive and nebulous but necessary.
- The renewable energy structure we are creating now is being made with high EROI fossil fuels.
- We have to become efficient enough for lower EROI renewables to “breed” themselves.

Plan Ahead and Retrofit Less

Arrive at the Future Prepared

(higher energy production potential and lower energy demand = greater resilience)

The development of Canada was a unique event exploiting many one-time opportunities.

We shouldn't expect the past to serve as the template of the future.

Particularly since we've degraded the resource bases upon which this country was built.

True Progress

- Sustainability is nothing more than social responsibility over many generations.

- Children get the better rice field.

Generational Transfer

Growth = Big Projects

- - Big projects = a few big deals
  - Big finance
  - Big overhead

- Stability = Small projects and upgrading

- Continuous upgrading and micro-grids = millions of small deals
  - Local trades and funding

  - High priced overhead cannot make a living in a localized economy

Whether human planned or nature forced, a change of the magnitude of incorporating human welfare and biophysical economics into national planning can only be successfully implemented if social cohesiveness is maintained.

Thank You!

Great Sources

- David MacKay Withouthotair.com
- David MacKay A Reality Check on Renewables youtube – sober overview.
- Not included in his calculations:
    - embedded imported energy (~35%)
    - Figures used are gross energy, not net energy (biofuels EROI probably 1:1 or lower)
    - Biofuels displace food
- Failing States Collapsing Systems – BioPhysical Triggers of Political Violence - Nafeez Ahmed

Great Sources 2

- Global Crisis – Geoffrey Parker
- Energy and the Wealth of Nations – Charles Hall (Mr. EROI)
- Energy of Slaves – Andrew Nikiforuk
- The Upside of Down – Thomas Homer-Dixon
- Vaclav Smil – basically anything but techy and dry.
- Immigration, World Poverty and Gumballs
- https://www.youtube.com/watch?v=LPjzfGChGlE
- The Spirit Level – Wilkinson and Pickett

The Second Big Gift

Fossil Fuels

- Explosion of learning
  - Aside from immense amounts of energy, fossil fuels eliminated the seasonality of energy availability.
  - Coal and oil and natural gas, with a little bit of infrastructure are self storing and always ready to use.
- Have we learned enough to lift us over the threshold of sustainability to the plane of endless progress?

Gas Tax

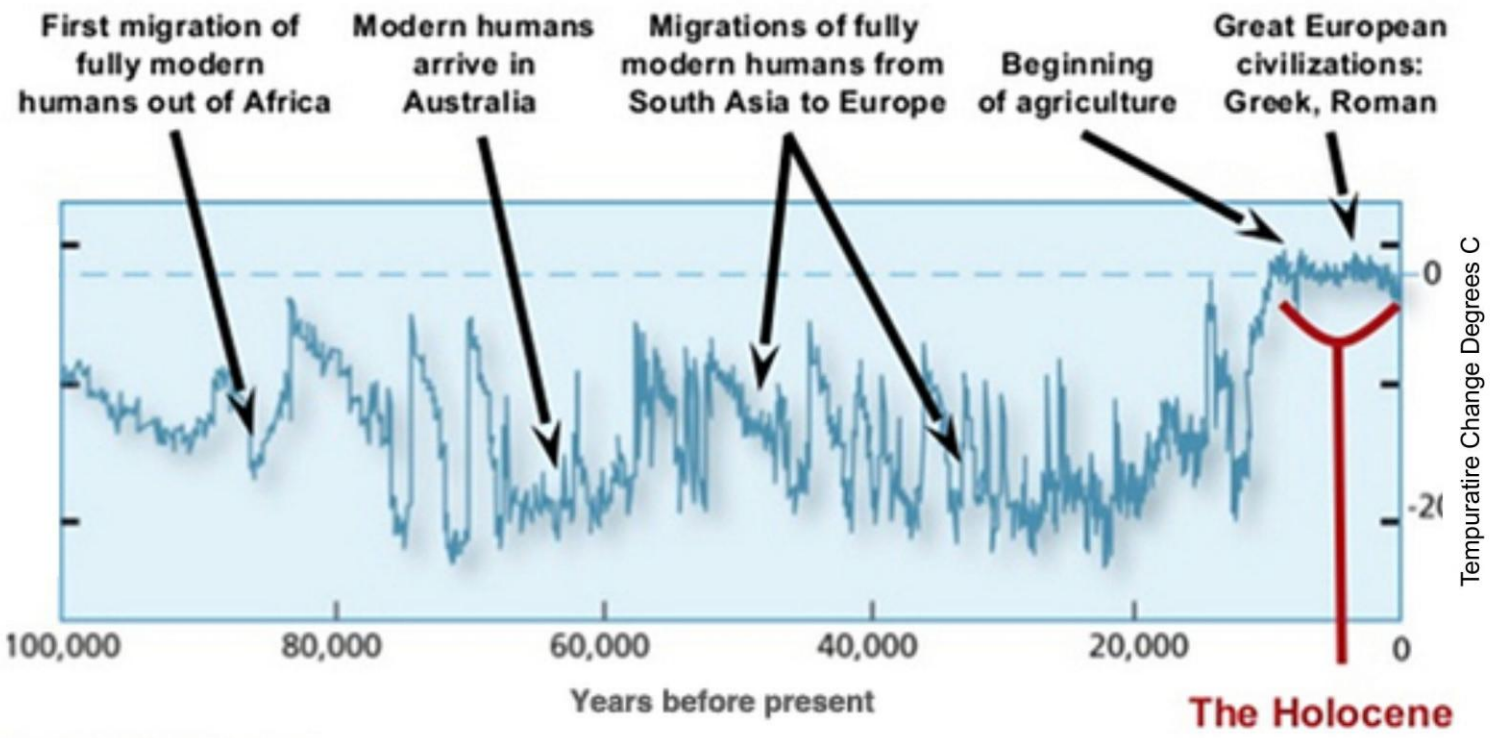
- **Gasoline Taxes**
- Tax structure will also shift as fossil fuel consumption declines. On average at present,
- Canadians pay 45 cents of tax per liter of gas and 39 cents per liter of diesel
- making up 33% of the pump price for gasoline on average and 30% for diesel.
- Federal and provincial governments will collect an estimated $24 billion in fuel
- taxes in 2018 (Taxpayer 2019). For passenger vehicles, the current gas tax of
- 45 cents on 37.2 billion L resulted in $16.7 billion of revenue. The distance driven
- was 349 billion km.
- Once the automotive fleet has been fully electrified, the electricity necessary to
- propel the same number of total kilometers will be close to 52 billion kWh. The
- average cost for a kWh in Ontario currently works out to about 20 cents in all. The
- tax needed to cover the loss in gas tax revenue would be 32 cents per kWh. But that
- would mean taxing all electricity, since it will be impossible to distinguish the
- energy input into personal vehicles. Furthermore, in most cases, drivers will be
- recharging at home or at the office from the power being generated by solar panels
- on the roofs of the buildings. The electricity may well not even pass through any
- grid meter.
- Hence, to cover the cost of road building and maintenance, either a flat annual fee
- will have to be charged per vehicle or vehicle owners will have to pay on a per
- distance
- basis. Right now that would work out to 4.8 cents per km. If taxes were to
- be levied on a flat charge per vehicle basis, each of the 19.7 million light vehicles in
- Canada could be expected to pay $850 per year as a mobility tax. High mileage drivers
- would benefit at the expense of those who drove less.
- Gasoline Taxes
- The road tax conundrum presented by EVs is also being studied in the United
- States, where electric car owners in Illinois are facing an increase in their annual
- registration fee from $17.50 to $1000.00 (FoxNews 2019). But does it need to be a
- conundrum?
- Tax policy is usually designed to be fair, but in the case of the shift from fossil
- fueled vehicles to EVs, fairness is exactly the opposite of what is required. The
- sooner EVs replace our current fleet, the faster carbon emissions will drop. This
- cannot happen quickly enough. In order to maintain road maintenance revenues and
- encourage the rapid retirement of the internal combustion fleet, ICE vehicles should
- pay an additional $100 licensing fee which goes up by $100 each year for 10 years,
- assuming the annual revenue target is $1000 per car. At the end of 10 years, EVs
- begin to pay a $100 license fee increasing by $100 annually until the $1000 is met.
- At the end of 20 years, there will be no ICE vehicles on the road, and the EVs will
- be carrying the entire road maintenance tax burden. During the first 10-year period,
- ICE vehicle owners will have an increasing incentive to convert to electric as the
- would be paying road tax as part of their gasoline cost in addition to an escalating
- licensing cost of up to $1000 a year while the EV driver is paying no tax at all.
- There will also be shifts in tax flows as energy production and manufacturing centers

EVs, the Low Hanging Fruit

- ***Changing national strategy***
  - ***Why build an eastern pipeline if the ground fleet is going to be completely electrified in 30 years?***
  - ***Why invest in manufacturing in Ontario – an energy have-not province – when Alberta is much closer to the energy (ng) supplies?***
  - ***Road Tax shift***
  - ***Political power rides an economic horse only so long as per capita incomes are high or rising.***
  - ***Road tax shifts from energy to annual fee.***

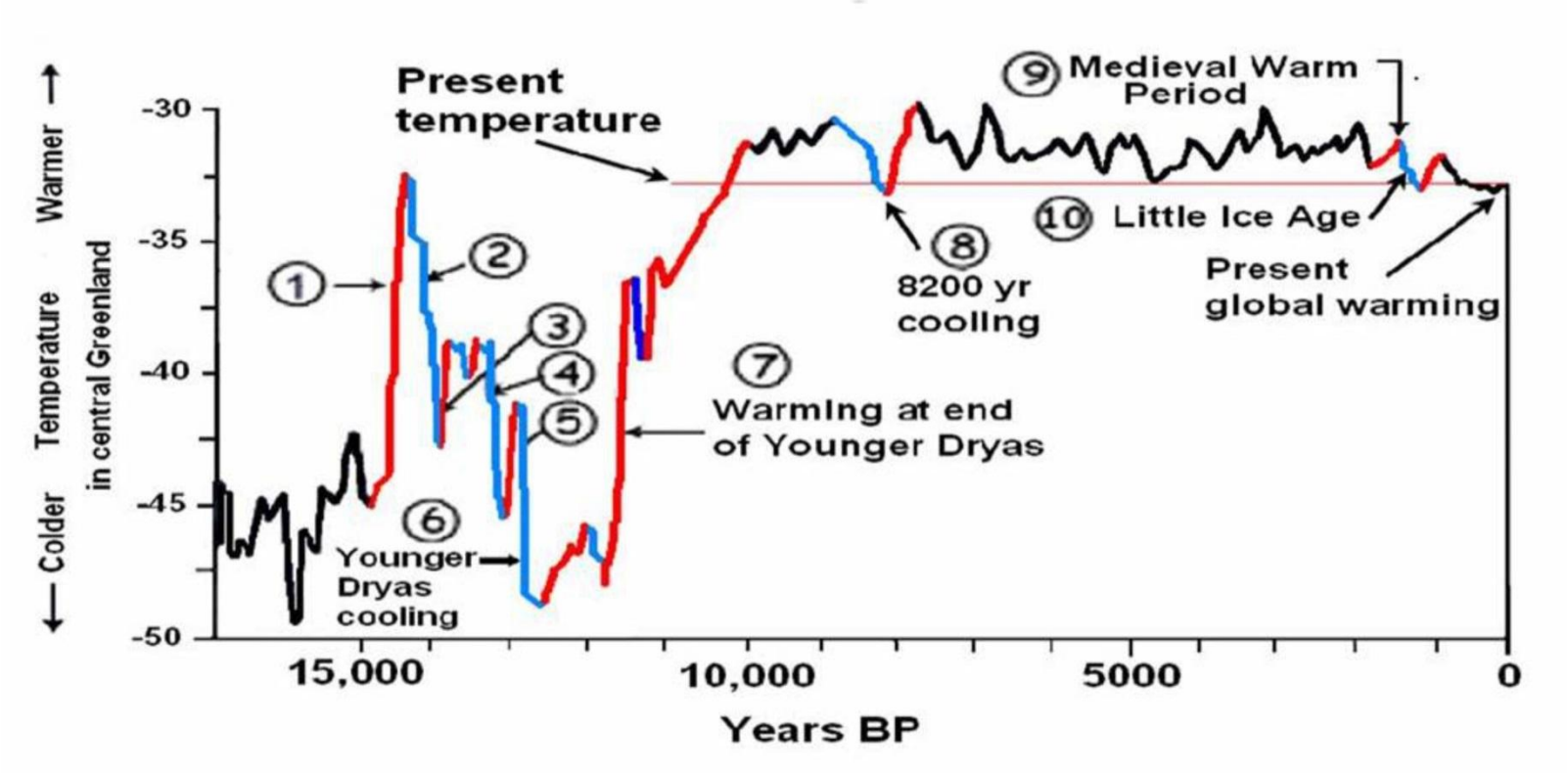
- ***Electric Vehicles (EVs): Deserve Special Mention***
- The automobile is a big part of our lives, and in the future, electric automobiles or
- EVs will fairly seamlessly take the place of gas-powered cars. The ranks of EV
- detractors are melting away in the face of these improvements in the driving
- experience.
- • The responsiveness of the electron-fueled drive system will become obvious to
- any driver. Tesla is famous for the “ludicrous” mode in its Model S which allows
- very rapid acceleration. But aside from the power the car can put on the road,
- there is the rapidity with which it can deliver the power. Electrons move virtually
- instantly making an internal combustion engine feels comparatively sluggish.
- • Despite the power that a big V-8 can produce, it takes time for an open throttle to
- allow the airflow and fuel delivery systems to make their way into the combustion
- chambers. Then it takes time for the valve settings and spark timing advance
- to adjust to the new demands and further time for the transmission to spool up
- and select the right gear. Then what follows is a strong push in the back as mass
- of the driver and passengers compress the cushioning in their seat backs.
- • Until the arrival of EVs, this process was taken to be instantaneous. But now, by
- comparison, it seems lethargic. This can be described as the difference between
- a strong shove in the back and being slapped forward. Electrons simply move
- faster than complex mechanical systems.
- • Lack of vibration, noise, and jerkiness.
- • Regeneration allows for mostly one-pedal driving and extended range.
- • Tire and wind noise are more obvious due to the lack of engine and mechanical
- noise.
- Electrifying ground transport is one of the easiest things a society can do to wean
- itself off fossil fuels. Transport burns gasoline and diesel fuel and is our largest

The Modern Tightrope



Conditions impossible for large scale and continuous agriculture. Last 10,000 years, a one time opportunity to stabilize, grow in numbers and learn.

10,000 Years



Beginning of agriculture and dense settlements. 300 year drought in Eastern Mediterranean ~1200bc, Greece wasn't heard from for hundreds of years.

Great Sources

- Charles Hall, Energy and the Wealth of Nations
- David MacKay, Sustainable Energy without the hot air. www.withouthotair.com
- Global Crisis, Geoffrey Parker