HEP as a career & Energy, Earth & HEP

Special lecture at the 2018 CTEQ school

Mayaguez, PR

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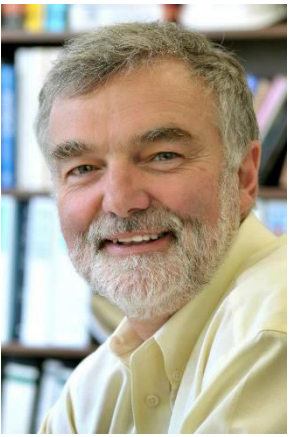


Intention of lecture

Tell a story & "entertainment" after heavy duty lectures

Two fold:

You are at beginning of career; I am at the end; give some perspective of a career in HEP (*why, how*), stepping outside of it and …..was it worth it ….

CTEQ school: inform & teach you

Discussion about "energy use in every day life"

- production & storage;
- how to discuss pollution;
- a model for the future
- what is impact of having the Standard Model on future energy sources
- status in Puerto Rico,

Interest of mine, driven by living in Puerto Rico & concerns about future

Probably too much, so may just stop

The beginning

Intrigued by science fiction in early teens; read everything; wanted to travel the universe and explore……..Anything is possible……

Reality started in high school, learned math & physics and beautiful connection between them….. Lots of possibilities, but also constraints on "traveling the universe"….. Optimism remained….

Netherlands

Do something about this (enable space travel)…..
Seemed obvious to continue physics where the high school physics book ended……. With pictures of particles and bubble chambers and CERN…… physics undergraduate

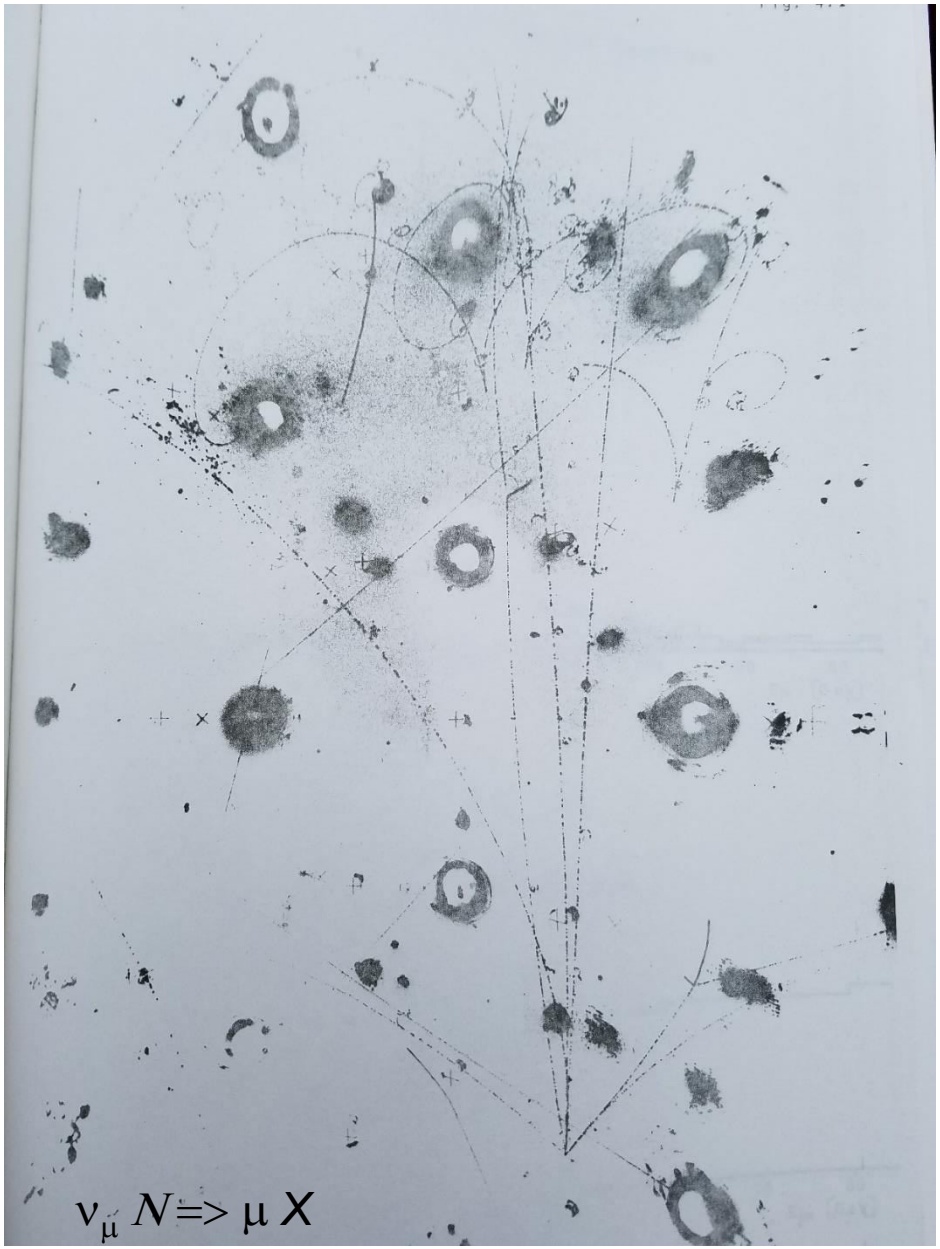
A few boring years of math and physics deep dive i.e. under graduate physics courses
Finally an interesting course: "Structure Functions in Deep Inelastic Neutrino Nucleon scattering"…… lectures chaotic, more questions than answers, new research, so joined research group….

Aachen, Germany, 1970's

Bubble chambers, neutrino interactions, computing, technology (*all unknown, new and exciting*)

Neutrino physics with Gargamelle bubble chamber

Career part



Learn how to turn "bubbles" → tracks → particles

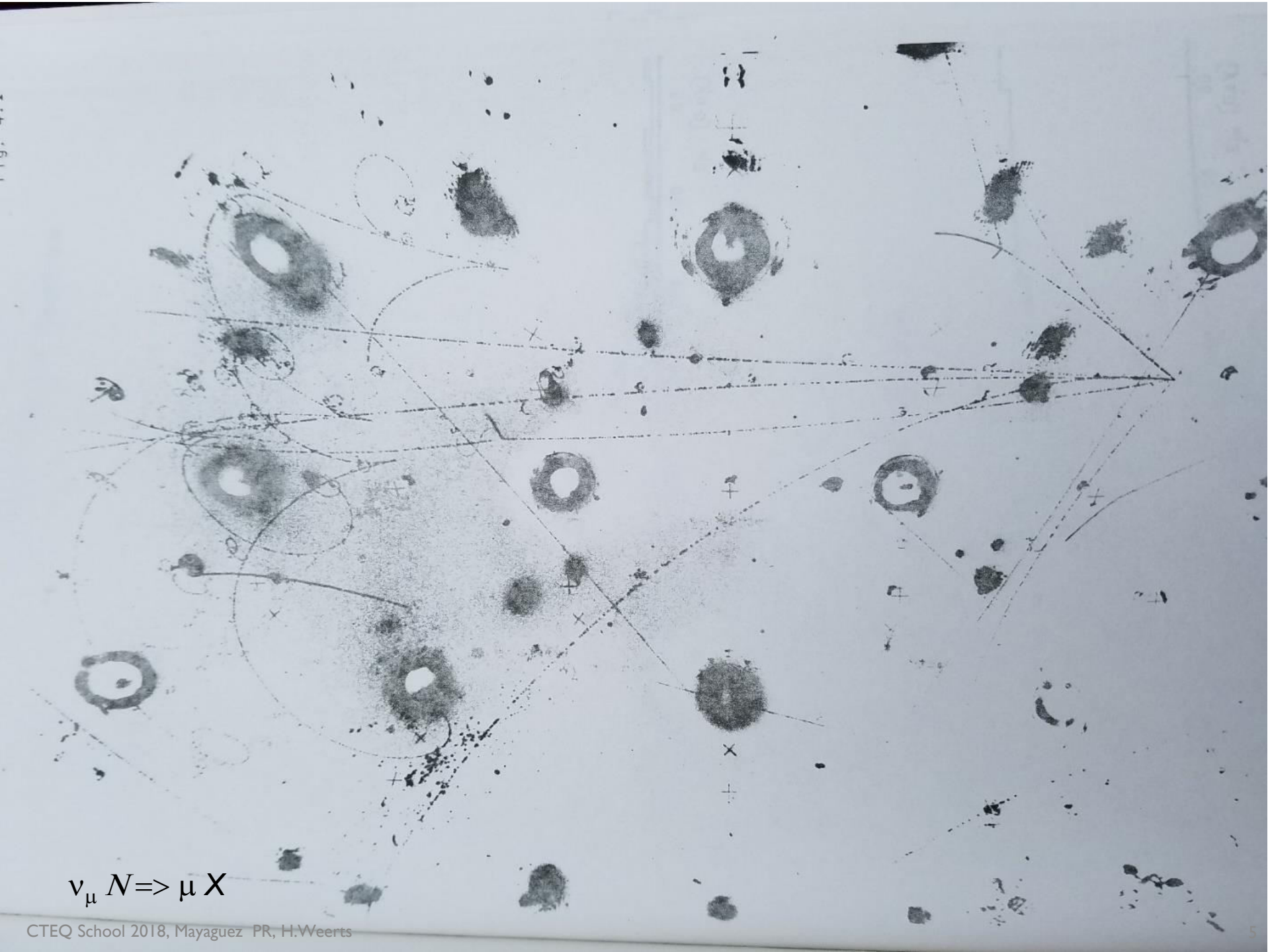
Measure them, reconstruct them online, build online systems, etc.

Learn a lot of <u>new</u> physics

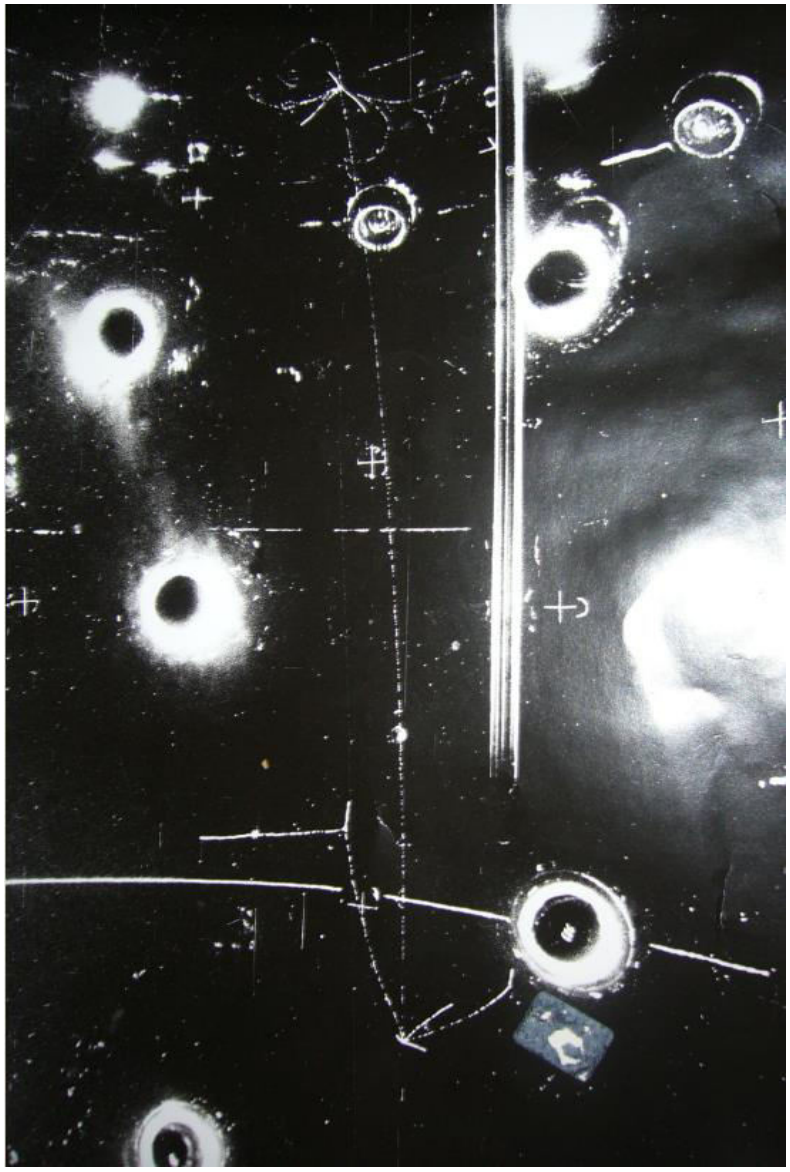
Goal: Collect and measure sufficient neutrino and antineutrino events to measure structure functions F_2 and xF_3 (*previous lectures*)

Pre PDFs and QCD

As many times before: experiment got side tracked by discovery of NC events

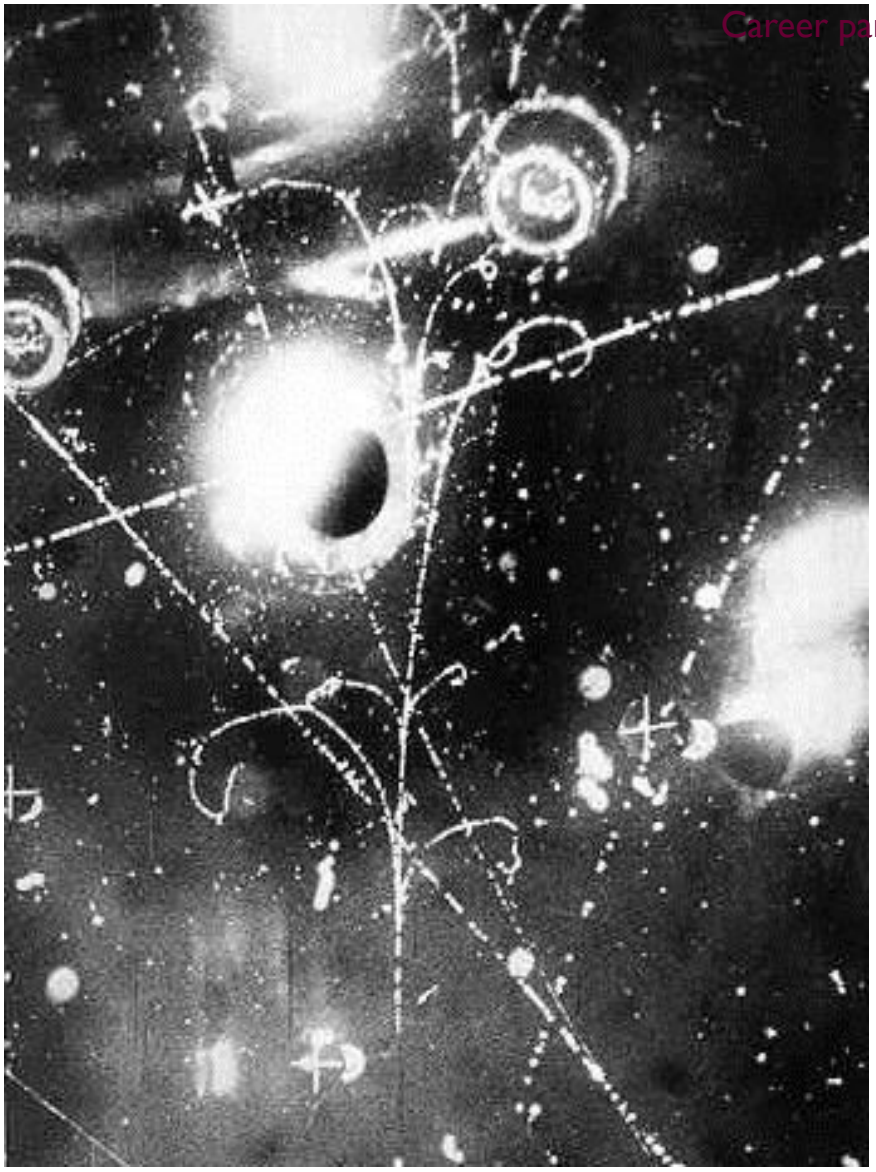


$\nu_\mu N \Rightarrow \mu X$



$$\nu_\mu N \rightarrow \nu_\mu X$$

Initial purpose of experiment



$$\bar{\nu}_\mu e^- \rightarrow \bar{\nu}_\mu e^-$$

Discovery of NC events became new focus

For HW: Later PhD thesis… initial QCD

Master thesis on NC π^0 production

The middle & end

Career part

Stumbling into the Gargamelle neutrino group at Aachen was one of best "steps" in science career

- Great physics: ν nucleon scattering & discovery of NC
- Being on discovery experiment was great
- Technological/computing problems (measuring events)
- Created friends for life, one you know: J. Morfin (still member of CTEQ)

Took for granted at the time

Continued ν physics at Fermilab with large electronic experiment
New environment, different approach/working style very stimulating
Physics not so great….

USA, 1980's

Lesson: Doing the same thing again & again in science is not the best way forward

Moved to proton-antiproton collider physics at Tevatron, took faculty position at Michigan State University.
Part of the Dzero experiment at Tevatron from start: responsibilities for large part of hardware; bringing up the detector and then QCD physics.
QCD physics interest led to CTEQ collaboration (first school in 1991); theorists and experimentalists work together to make progress.
Twenty years on Dzero (many also in CTEQ), from junior member to spokes person

~ 20 years

Had to go do something new; most asked why ??

The beginning & the middle

Career part

Being part of Dzero was a conscious choice for variety of reasons

- Great physics potential of Tevatron (unique in world at the time)
- Top quark discovery and many new, unique measurements
- Technologically very challenging / cutting edge
- Need of precision QCD at Tevatron was "my reason" for CTEQ
- Established many personal relationships with colleagues worldwide

A unique experience

Twenty years on Dzero and towards end too much management and away from science.
Combination of teaching "old physics" and particle physics research not well suited for me; realized that I wanted to do research only.

USA, 2000's

Lesson: Doing the same thing for too long not good for me; need something new

Move to Argonne National lab; gave up tenure (professor had seemed like the ultimate goal before); to lead High Energy Physics Division– able to direct and shape that program.
Continued effort on realizing ILC/CLIC (e+e-) for ~8 years; still in the works
After ~10 years led all physical sciences at Argonne (400 people); incredible spectrum of science, but too much management i.e. no time for science

Lesson: Being responsible for ~400 people & large DOE science budget…. too many rules

Some advice & possible lessons for you

Career part

Your are at beginning; I am at end => some advice, observations

Had several career paths and have seen a lot of science careers

You have something unique: have learned/are learning to formulate a question/problem and propose & execute an approach to get an answer (experiment, theory etc.)

Possibilities are enormous and manifold

Most of you are students/postdoc.

Advice: Change institution/environment; you learn new things & new ways to work

What are the career possibilities ?

Some advice & possible lessons for you

Some possibilities:

Most of us want to be "professor of physics" I did this

Teach & research or teach

Environment we know & love; your advisor did that & there is tenure. Not for everybody & not enough positions

(teach & research; research typically small efforts, problems; set your own pace, limited by funding)

Students good influence

Scientist not university (labs, facilities, industry, etc.)

Wide spectrum of possibilities/fields; perceived uncertainty (no tenure), more group research & larger scale problems, no teaching.

(pressure from funding source to produce; able to do very large projects)

Other (industry, finance, government, etc.)

Apply your skillset to other problems; leave what you "were born to do"…., many possibilities

(always pressure to produce; electronics, computing, modeling for many purposes(finance, insurance, other sciences), policy for science, etc

The tenure myth: "tenure is only at universities". However if you are good everybody wants you to stay -- so you have "tenure".

Career in physics -- summary

Summary advice:

- Use opportunities that come along
- Be willing to take a risk (that is what science is about)
- Be willing to make a change (it is fun)
- Be yourself; your new contribution adds to spectrum of opinions and ideas that drive science forward (diversity)

Not everybody agrees, but it was for me

Most rewarding for me:

- Be part of a worldwide community that has a common science goal (particle physics)
- Be at the edge of science & technology
- Work with great colleagues, get to know them, form relationships
- Along the way did some great science i.e. made progress

Most disappointing for me:

- Space travel not in reach with current knowledge
- We are trapped on planet

If we are stuck on earth, we might as well make the best of it ➔ next topic

Career in physics -- summary

Talked about career part only

of course

there are many other aspects and sides to your life, which play an important role in your future, especially your personal life, which often dictates directions and/or sets boundary conditions.

It did in my case

Energy

Why discuss ?

- We are in Puerto Rico & a lot of discussion about energy generation & distribution after Maria destruction in 2017
- Argonne battery/energy storage research
- What do we learn from SM -- now that we "know it all"

Availability of easy energy & everywhere enables modern world

Without it we would be in the middle ages…..

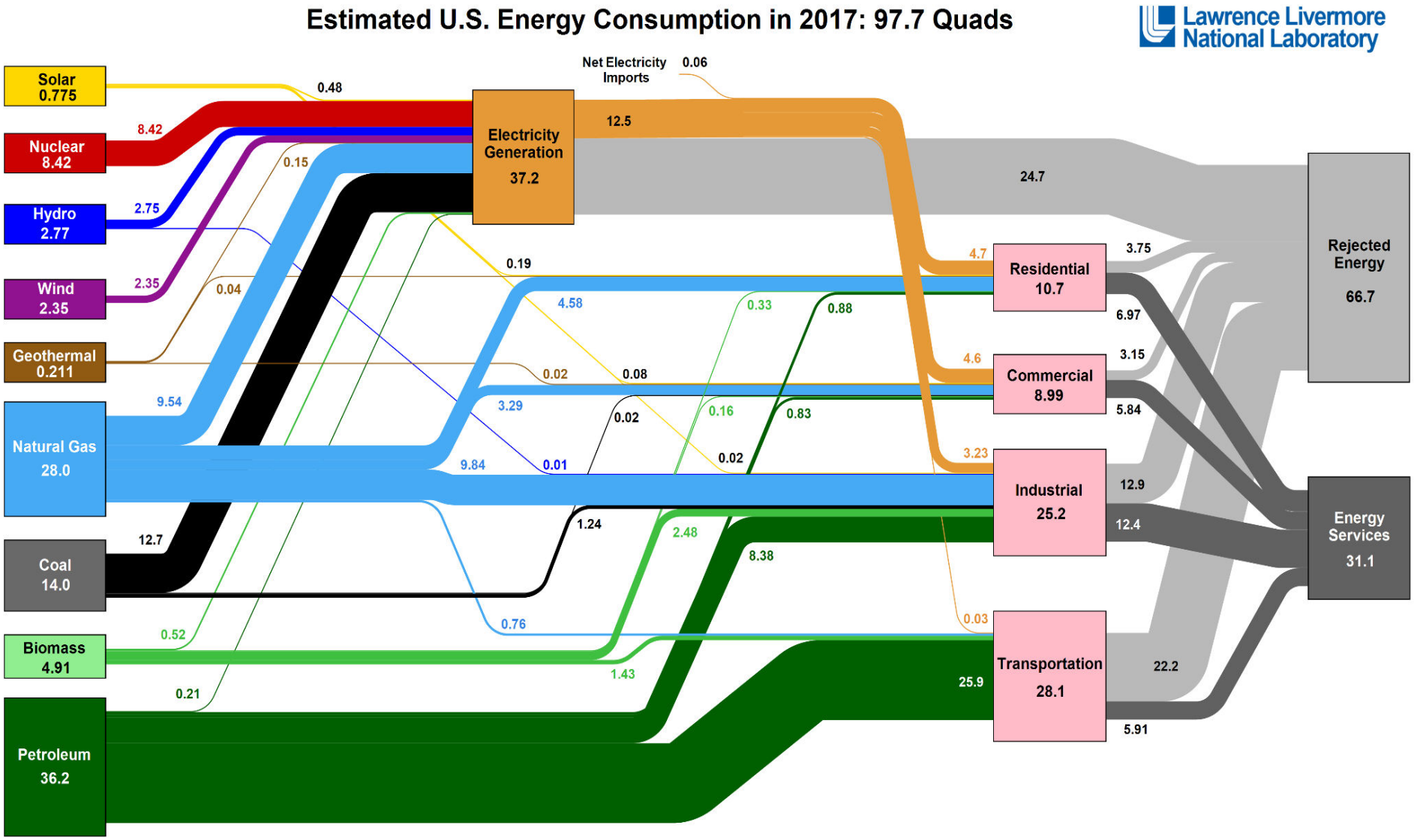
Our need globally for "energy everywhere" will only increase

Everyone needs access for current lifestyle

How do we use energy ?

Energy use currently

Energy generation and use in the USA



1 Quad = 10^{15} BTU; 1 BTU = 1.055kJ = .293 Wh

97.7 Quads = 28600 TWh

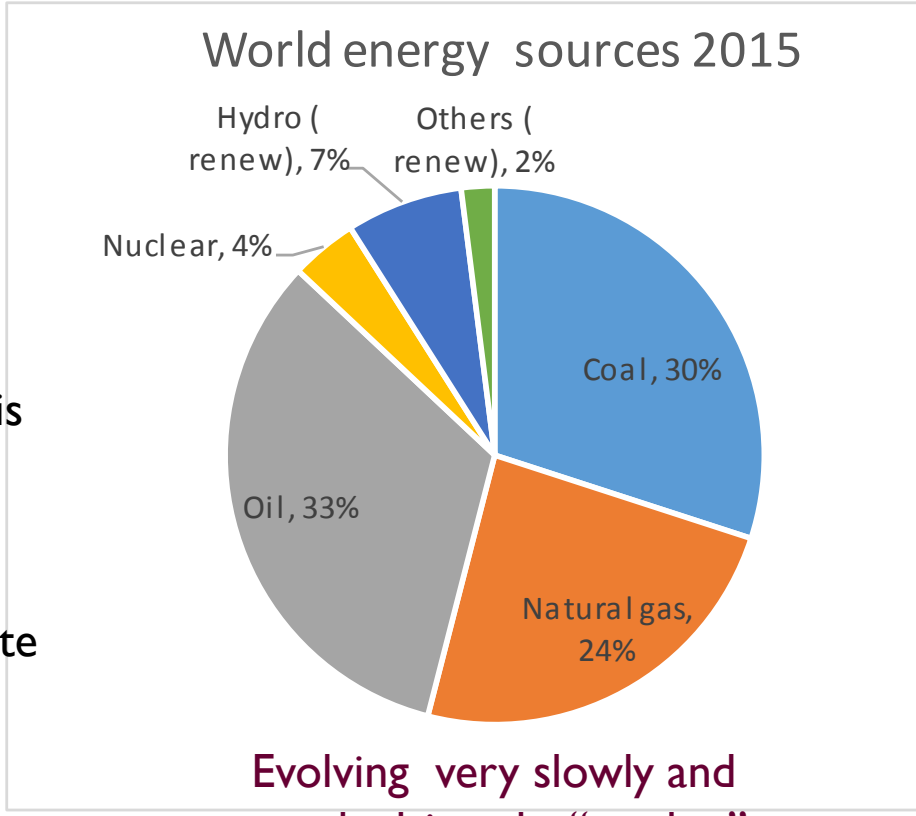
Energy use currently

Lessons from previous energy use picture

Create energy on demand from fossil fuel mostly (coal, oil, natural gas)
Most energy ultimate goes into heat. This energy currently lost

There is no recycling of energy (once used it is gone)
Used to move things, processes, light. etc

We do not store energy to first order (generate on demand i.e. we have over capacity to make sure it is always available)



Evolving very slowly and mostly driven by "market"

Ultimately everybody on planet wants this much energy (as the US consumes)

Energy use currently

Consequences

Burning fossil fuel seems innocent and there is no immediate consequence for individuals.

BIG debate about impact of exhaust products on planet eco-system

- Most think that burning fossil fuels will have impact
- Global warming data seem scientifically clear
- Debate with non-scientific community about link of global warming & human cause
- People who doubt/question link do not see connection for variety of reasons (all non scientific)

Many people doubt everything until "they experience it"….. personally

Amazing opinion NYT: "planet could be flat"……

Tried to think of way to illustrate in easy understandable way, the impact of burning fossil fuels…. to convince the "doubters" that there is a problem.

Nobody would put the exhaust of their running car into the living room and claim air quality is just fine

So came up with the "planet as our garage" model

Planet as our garage

Planet earth is a closed system. This means energy from the sun can penetrate, heat it up, and some of that energy is radiated back into space.
However no "matter" can leave the planet.

So in that sense (on a small scale) the planet is like your garage with doors closed. When doors are closed nothing can get in or out.

We all know that when garage doors are closed and we start car in garage it becomes unpleasant quickly after short time (you can verify this your self….. and how long it takes)

Everybody agrees…

The atmosphere of earth is like a GIANT garage…….

So when we turn cars on "exhaust systems" go in the GIANT garage and stay there

Question: when we turn all cars (and other fossil burning entities) on and compare to our small garage with one car, how many minutes has the "car" been running ??

This can be calculated or modeled……

Planet as our garage

Model

Build a model where we turn on all cars and other fossil burning entities at some time and accumulate (remember nothing escapes).

Get all information from the government or industry resources

Garage is 18ft long, 12 ft wide, 8 ft high and contains one car idling at 600RPM

This is the base unit in which everything is expressed

Atmosphere above us is 10km thick(troposphere)
A standard car & commercial vehicles get 25mpg, drives at 30mph at 2000RPM
A semi truck gets 6mpg.

#garages in atmosphere: ~10^{17}

cars ~ one billion , 10^9

A personal car runs on average 2 hours/day (5 days/week)
Commercial vehicles run 8 hours/day (6 days/week)
Semi trucks run 7 hours/day (5 days/week)

Start running cars like this in 1950 and accumulate…..

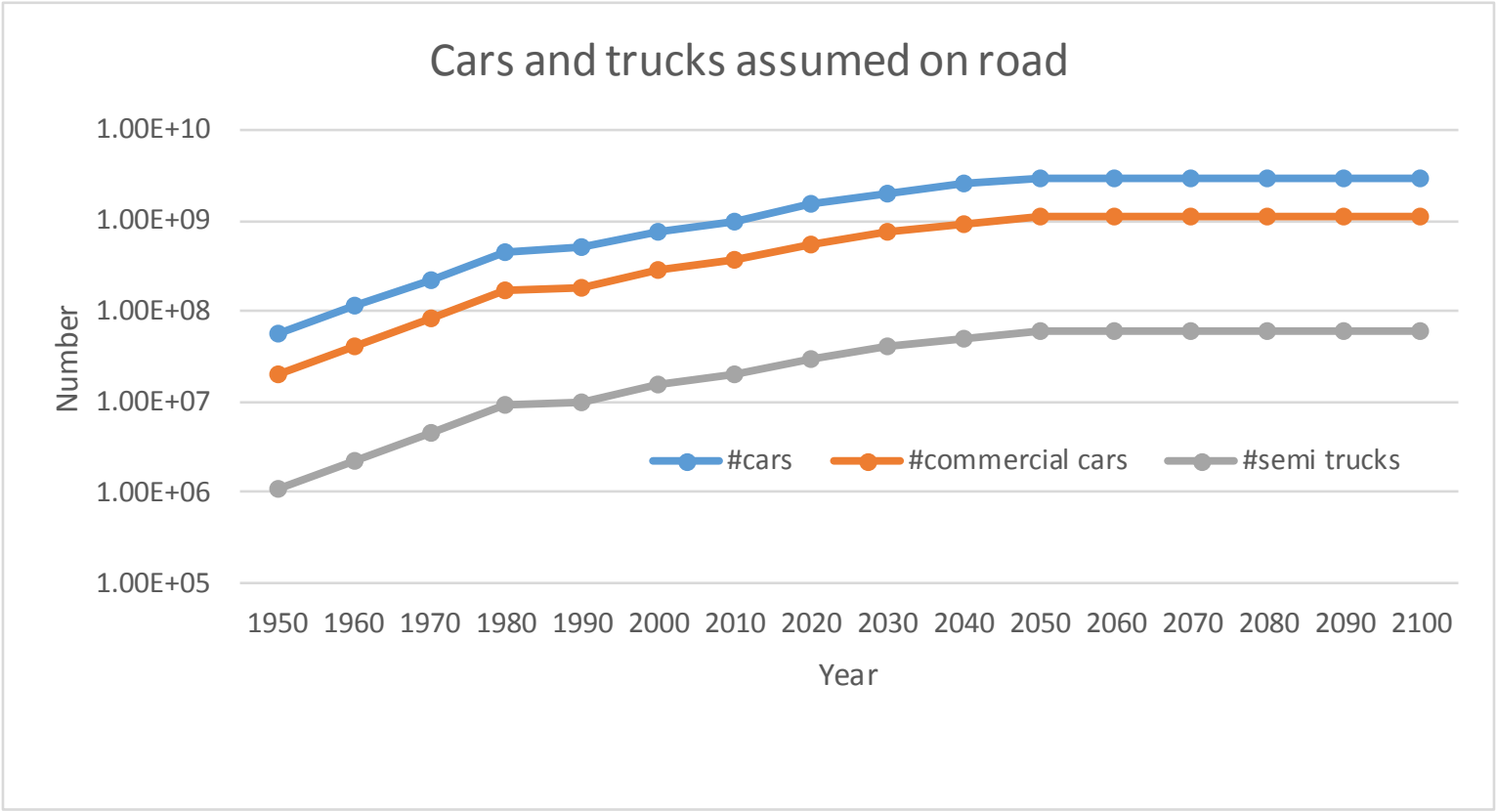
Assumption: planet absorbs exhaust gases (especially CO2), so assume that 50% of exhaust gases produced each year are absorbed and do not stay in atmosphere (garage does not absorb)

Planet as our garage

Model

Statistics on cars or better vehicles:

Cars used vs year

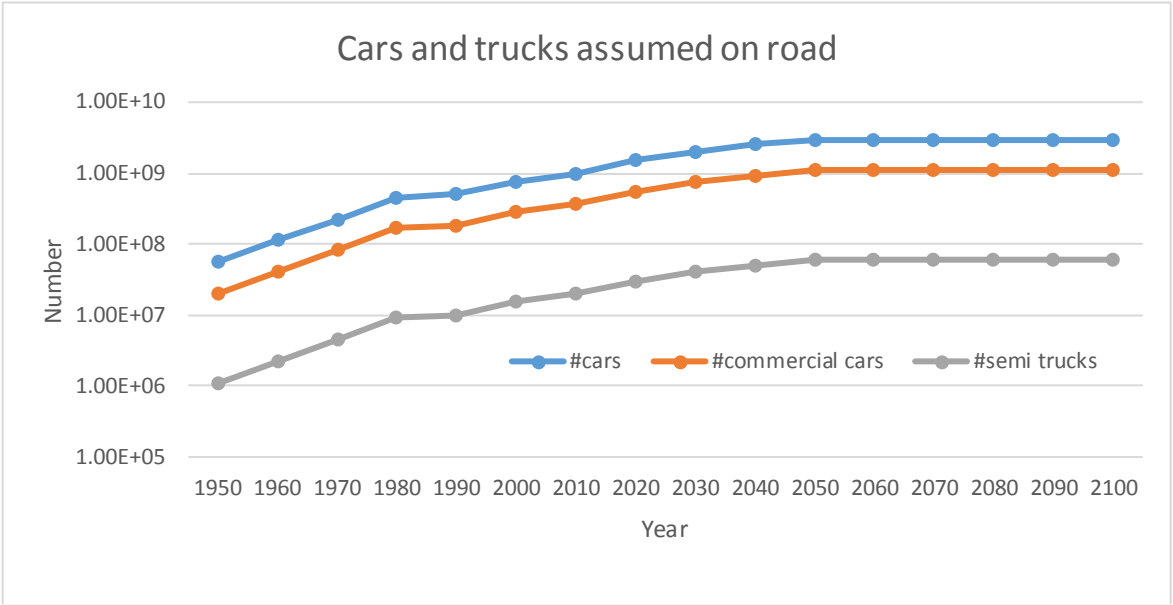


Planet as our garage

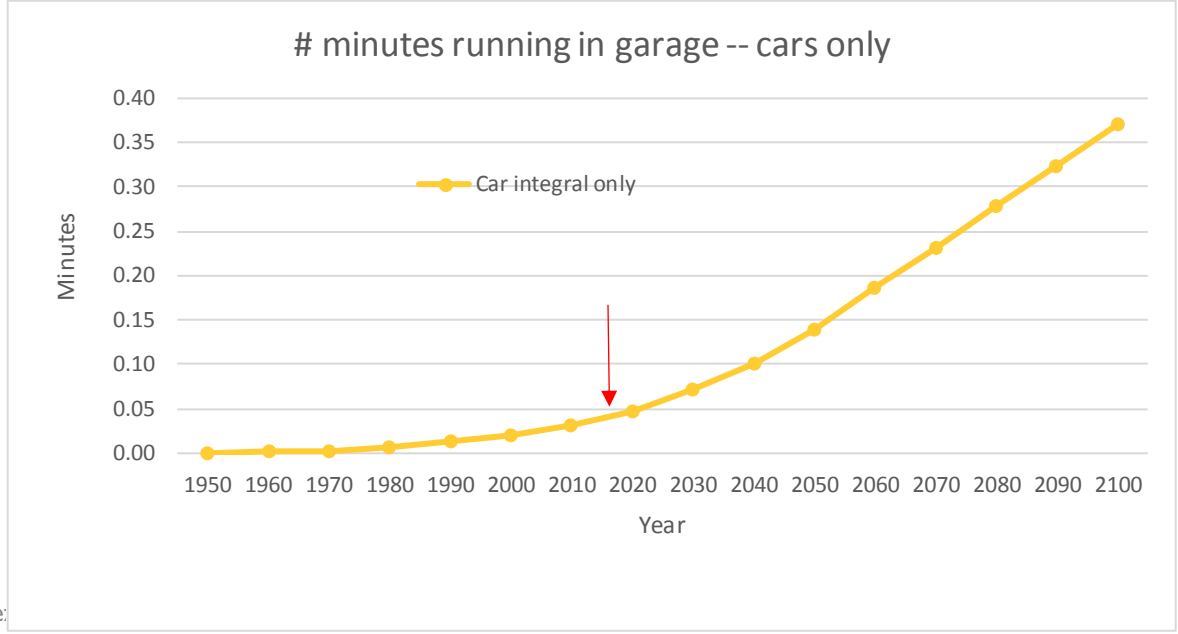
Model

Cars only

Cars used vs year



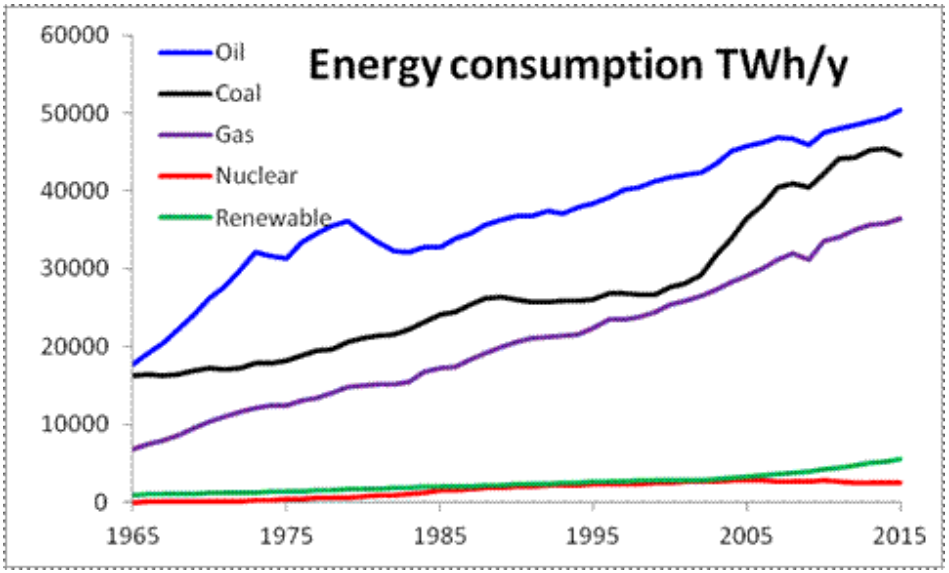
Impact of cars



Planet as our garage

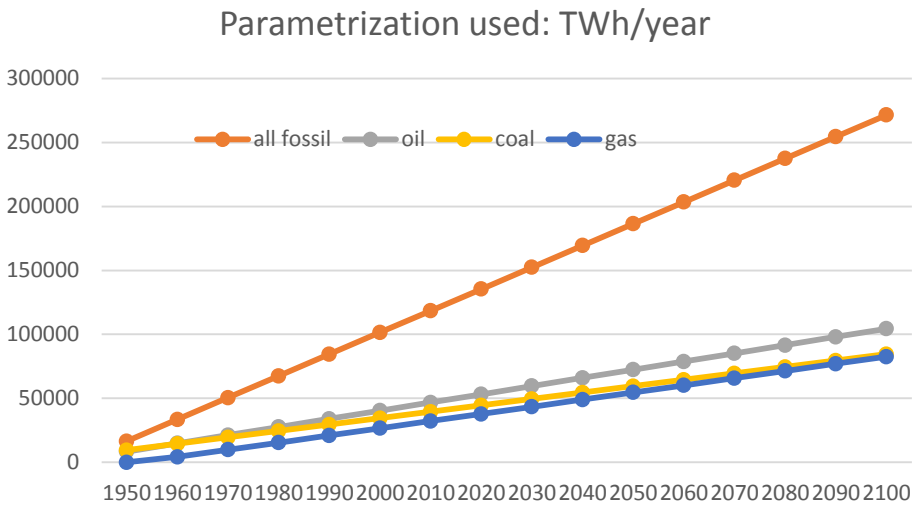
What about power plants…..

Worldwide consumption



Model

A little tricky… but government has all the numbers



Government tracks how many BTU (British Thermal Units) are burned per kWh.
Use to convert to "car idling in garage (= 677 BTU/min)".

BTU/kWh	Coal	Petroleum	Natural gas
	10432	10852	8120

Impact on our planet garage

1 TerraWatt = 10^{12} Watt

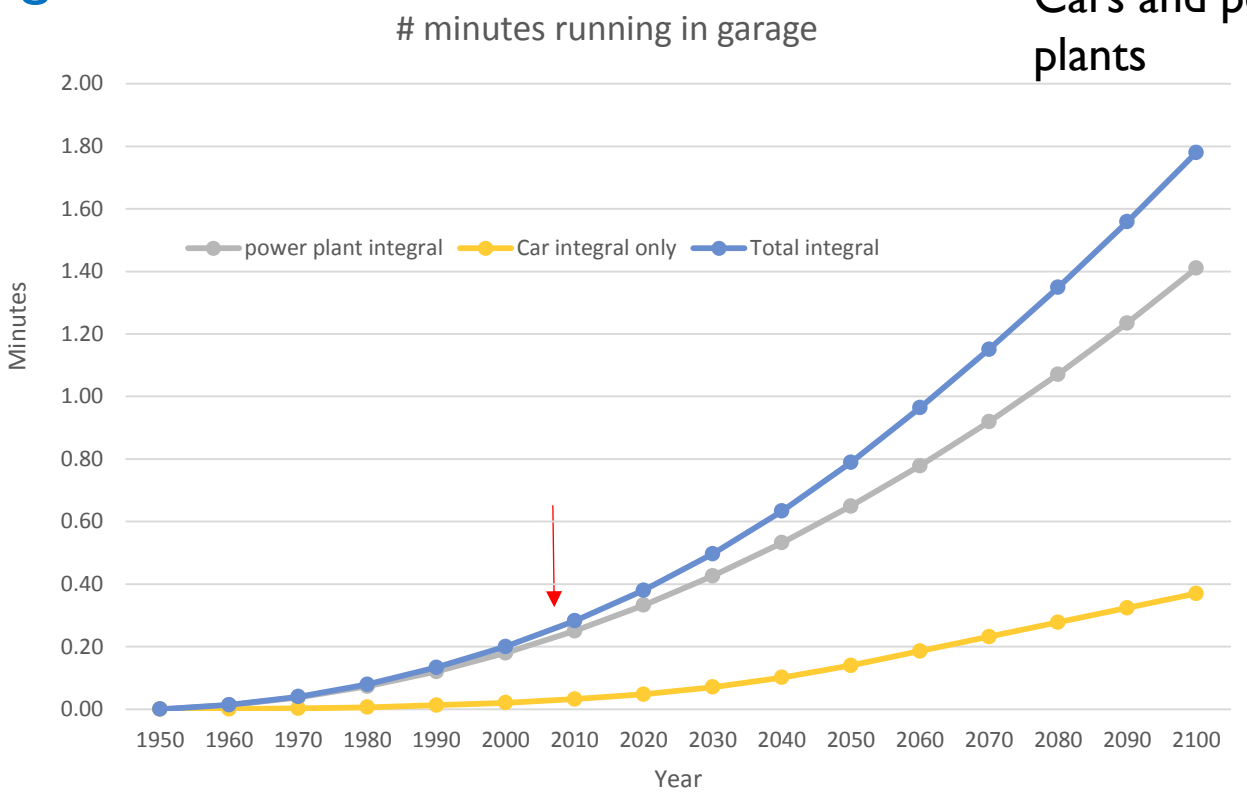
Planet as our garage

Model

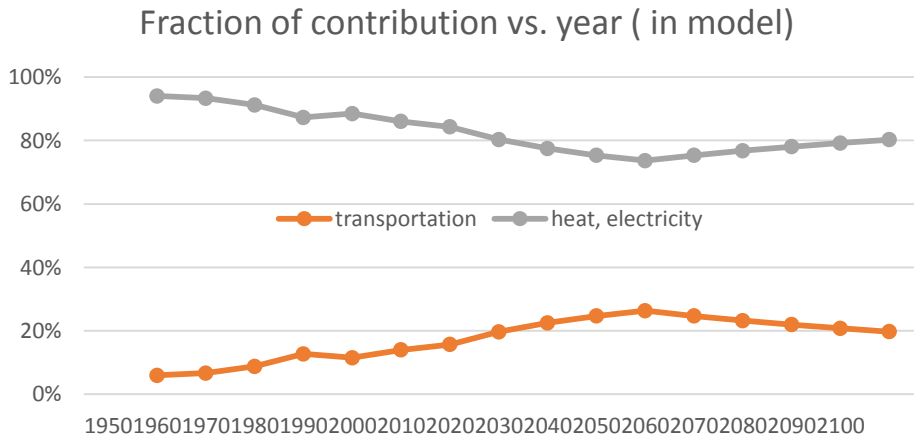
Cars and power plants

Impact of all

Air height: 10 km



If we keep going it will be ugly.



Do the experiment in your garage

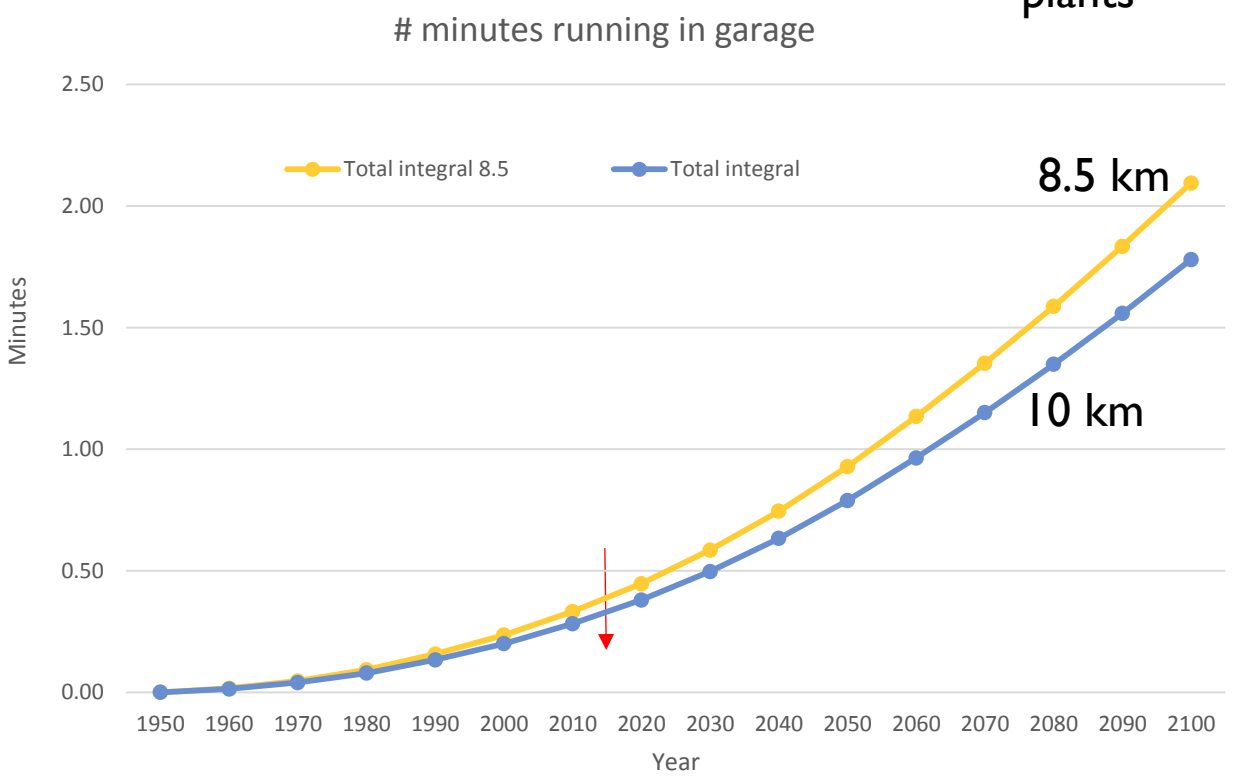
Planet as our garage

Model

Cars and power plants

Impact of all

Air height: 10 km and for 8.5 km (if density was uniform and equal to sea level)



Bad & shortcomings

- Simple model of atmosphere (no density variation)
- No diffusion over time' assume uniform across all atmosphere from start
- Simple model for cars, trucks, power plants -- *really bad* ?

Good

- Everybody can relate to it and test at home
- Can be used to do local models for cities for example (next step)

Energy use future

Things will not change very fast
Energy demand will continue to rise worldwide

Future vision:

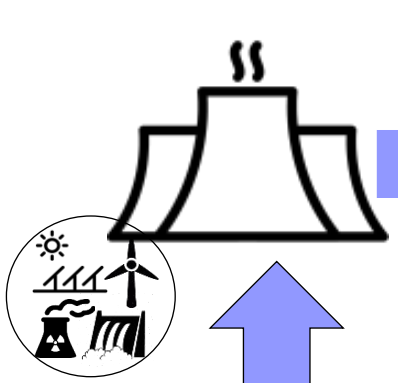
Move from using the stored energy of the sun (over millions of years i.e. fossil fuel) to using the energy of the sun now (photovoltaic, wind) plus others: hydro, nuclear

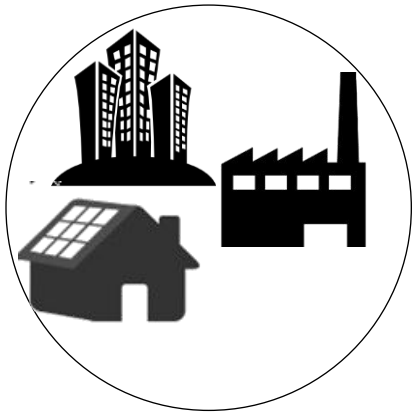
Expressed by many; in one way or another

Fossil fuel & respond to demand

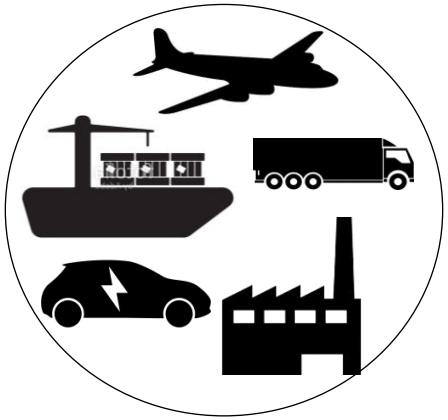
Renewable (with large fluctuations) and energy storage

Current picture: everything starts from fossil fuels





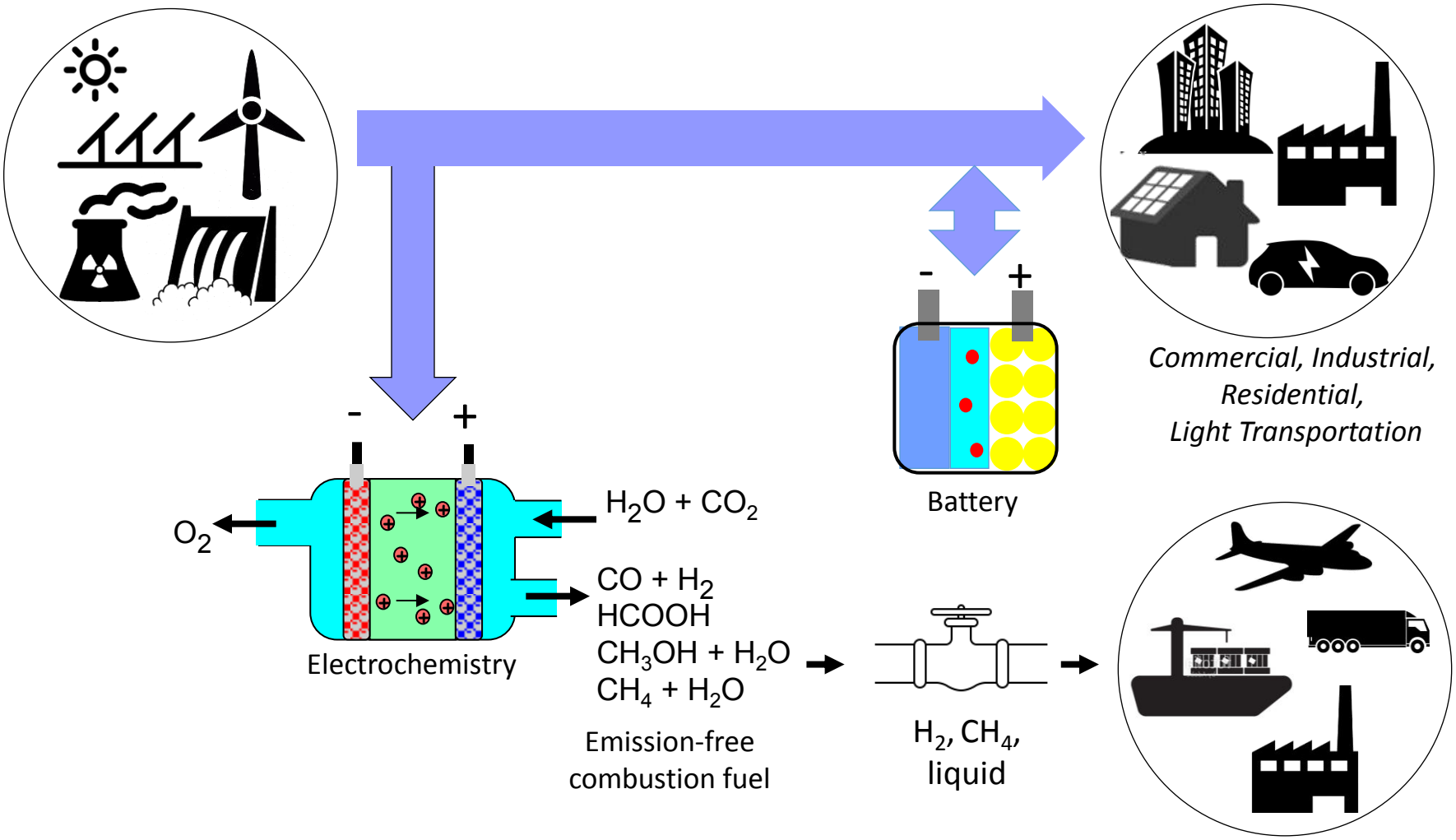
Commercial, Industrial, Residential,



Transportation, Heating, Industrial Processes

- Fossil fuel drives the system
- With all the consequences

Disruptive Vision: A Fully Integrated and Decarbonized Energy Network



- Unites separate electricity, natural gas and oil carriers
- Integrates existing pipeline infrastructure
- Levels load for generation

From G.Crabtree, UIC

Energy use future

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Energy demand will continue to rise worldwide

Future vision:

Move from using the stored energy of the sun (over millions of years i.e. fossil fuel) to using the energy of the sun now (photovoltaic, wind) plus others: hydro, nuclear

Expressed by many; in one way or another

Fossil fuel & respond to demand → Renewable (with large fluctuations) and energy storage

Consequences:

- Ultimate energy might be free i.e. no cost ….
- Need electrical energy storage (batteries)…. Cheap ← Critical !!
- Nearly everything that moves (light duty) is powered electrically (cars, SUV) and/or hybrid (trucks, planes)
- Adjust to local environment …….

Energy use future

Where are we with batteries and their use ?

Main technology for future batteries are Li-ion batteries (LIB, in your phone), but Pb acid (starts your car) continues to play role.

Mainstream: Li-ion will power electric vehicles and possible battery for home energy storage, may be electric grid storage.

Can not do this justice; many aspects to field

In next few slides will show:

- Price of Li- ion batteries and forecasts
- Where is the production in world
- Growth of electric and hybrid car market i.e. are we changing ?

Give some sense of direction

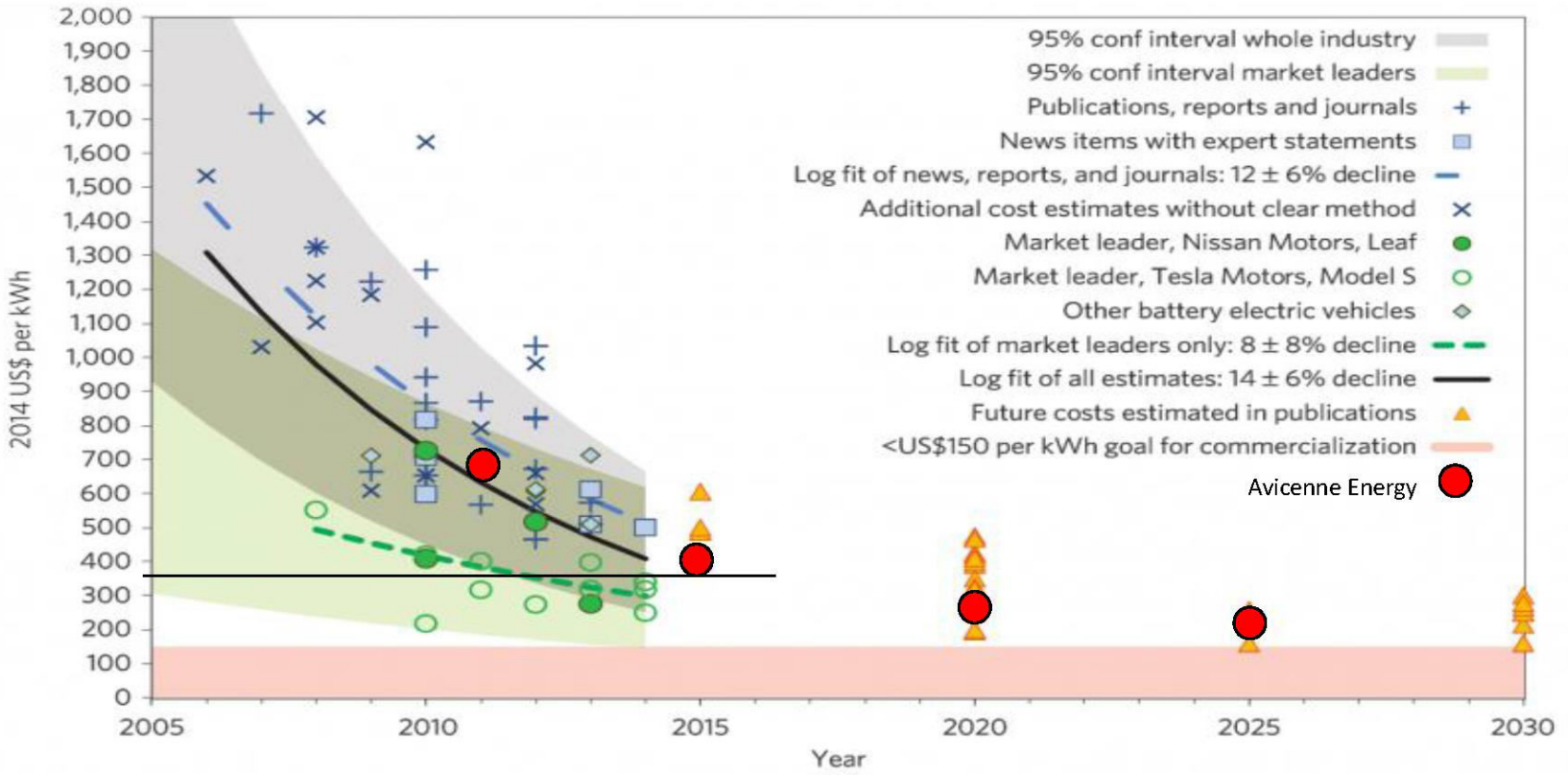
How much energy is needed in a battery ?

- Nissan Leaf 30kWh
- Tesla Model S 90kWh
- Future BMW 100kWh
- My house to run for ~10 hours needs ~10kWh (some air is on); worst day is 50kWh for one day. (PR: ~$0.20/kWh from PREPA)

Price of LIBs

Overall goal: ~$150/kWh

LIB PRICE FORECASTS



Source: ***Rapidly falling costs of battery packs for electric vehicles,*** *Nature Climate Change , March 2015*

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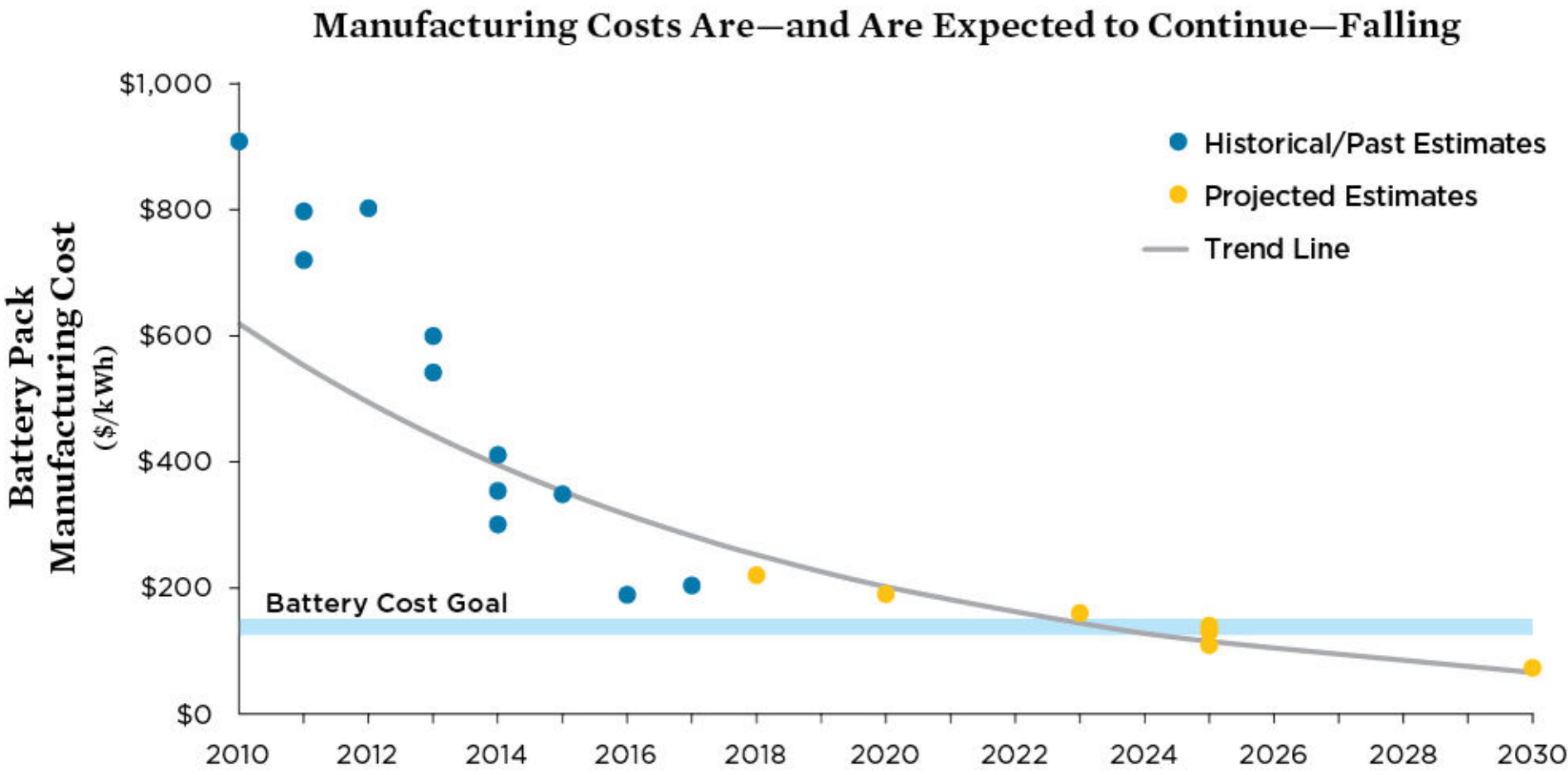
From talk by C.Pillot; Avicenne Energy; AABC, June 2018

Price of LIBs

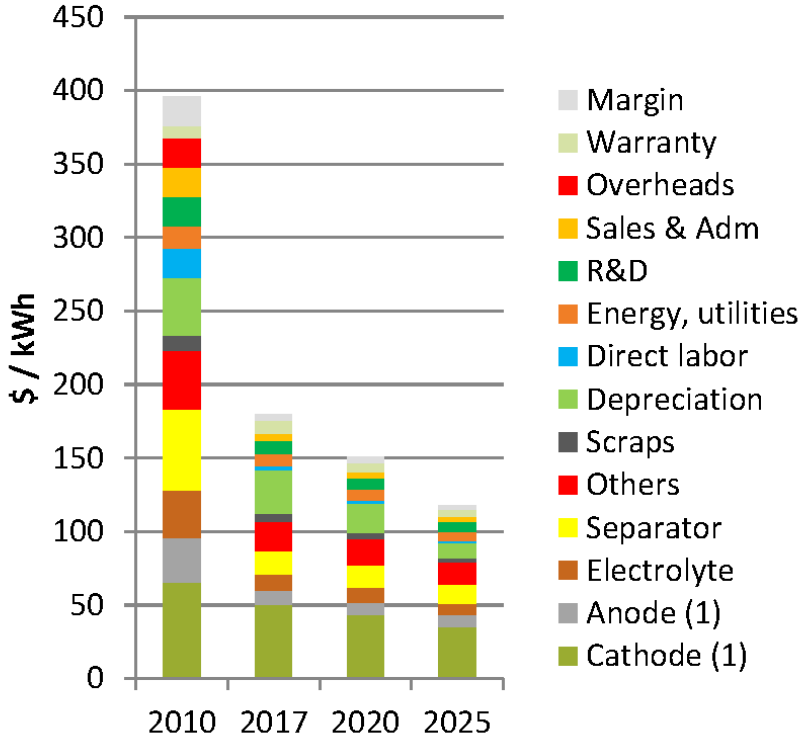
Overall goal: ~$150/kWh



Where do costs come from ?

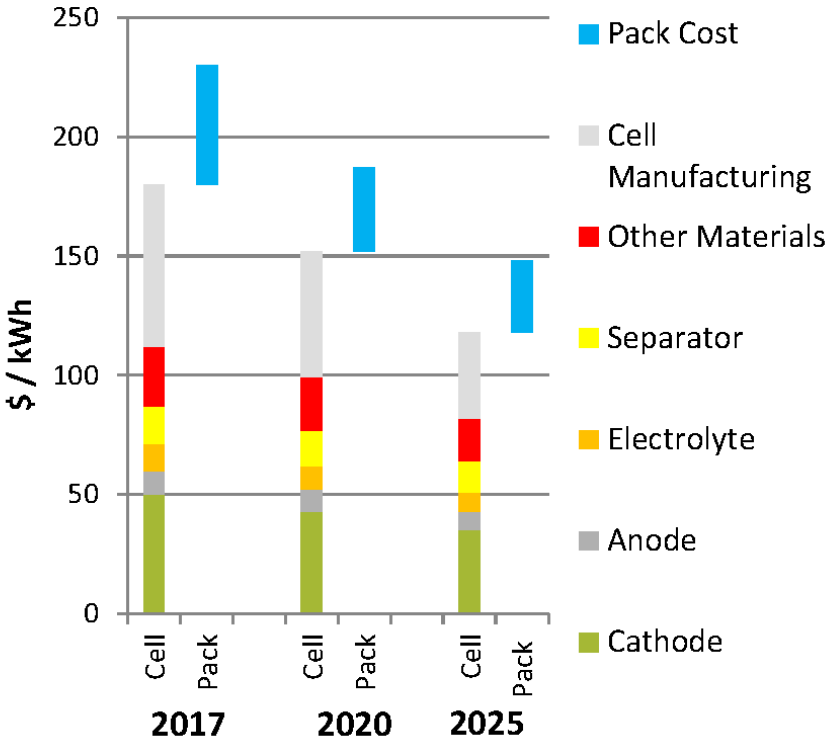
LI-ION BATTERY COST 2015-2025

LIB cell average **cost** (40 Ah pouch) (EV design ; NMC cathode)



(1) Active materials only
Source: AVICENNE ENERGY 2018

LI-ION BATTERY PACK **COST** FOR EV



** For Production > 100 000 packs/year*

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From talk by C.Pillot; Avicenne Energy; AABC, June 2018

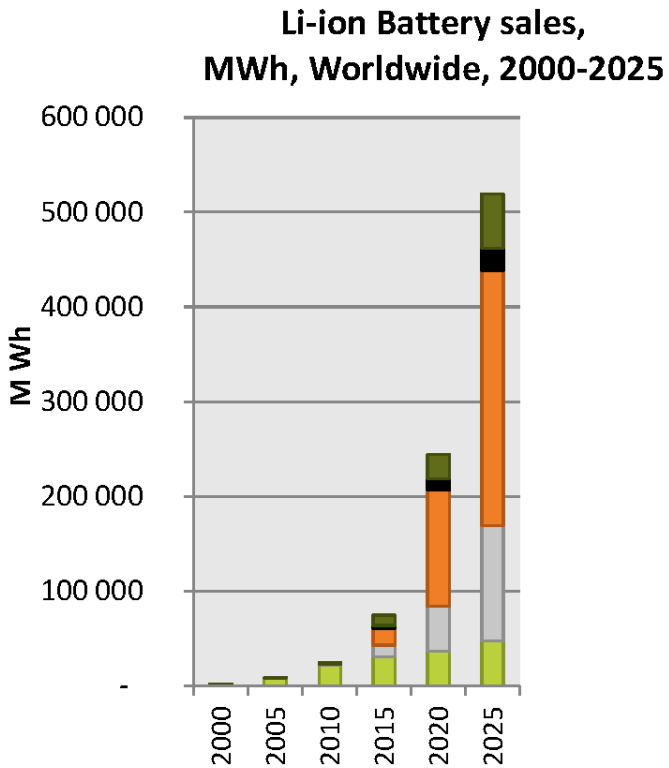
Growth of LIB market in MWh

CAGR= Compound Annual Growth Rate

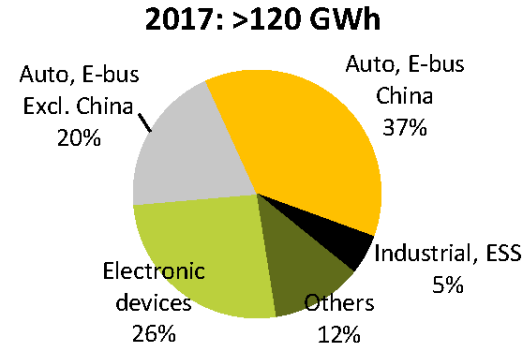
LI-ION BATTERY MARKET FORECASTS

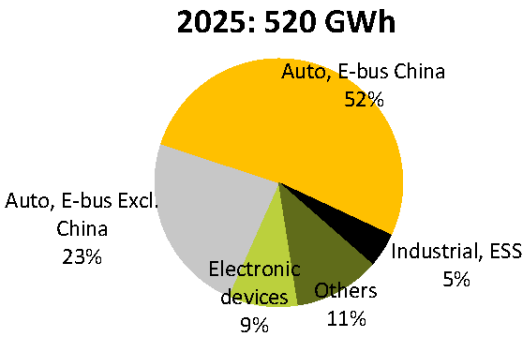
From 120 GWh in 2017 to 520 GWh

CAGR 2017/2025
+21 % per year in Volume



	CAGR 15/25 (Realistic)
Others	18%
Industrial, ESS	23%
Auto, E-bus China	31%
Auto, e-bus Excl. China	25%
Electronic devices	5%





Others: medical devices, power tools, gardening tools, e-bikes…

Source: AVICENNE Energy 2018

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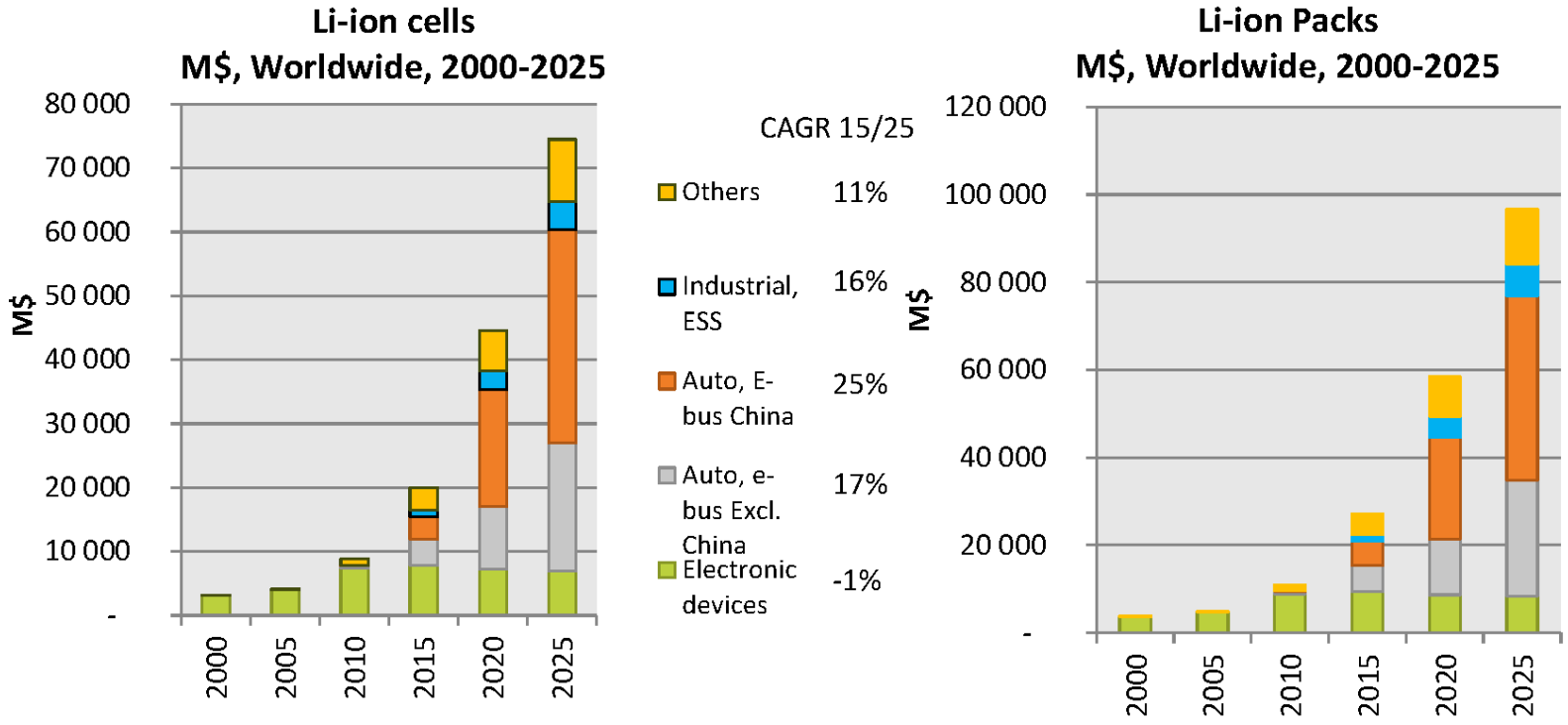
From talk by C.Pillot; Avicenne Energy; AABC, June 2018

Growth of LIB market in $'s

LI-ION BATTERY MARKET FORECASTS

CAGR 2017/2025 +21 % per year in Volume
Cell: +14% per year in value
Pack: +13% per year in value



Others: medical devices, power tools, gardening tools, e-bikes…
Source: AVICENNE Energy 2018

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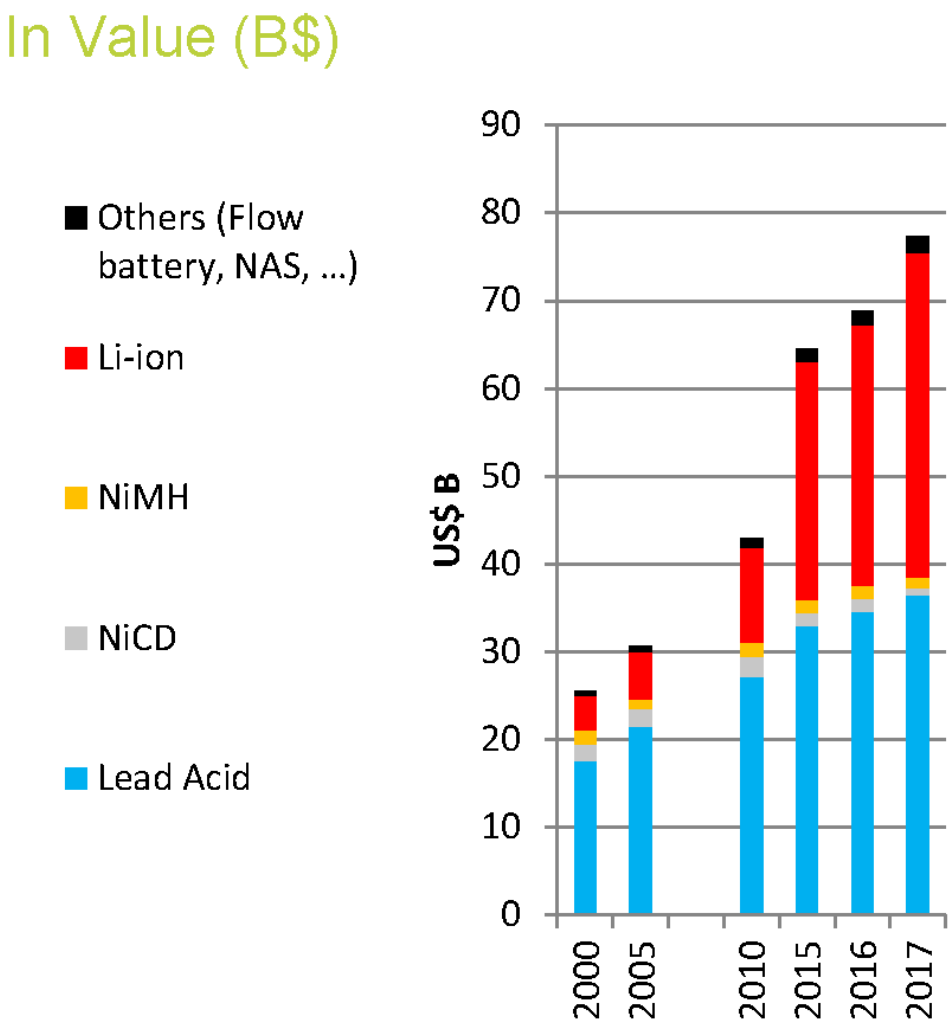
From talk by C.Pillot; Avicenne Energy; AABC, June 2018

Growth of different battery technologies



Source: AVICENNE ENERGY, 2018

Increase in Li-ion is clear

From talk by C.Pillot; Avicenne Energy; AABC, June 2018

Forecasts for "electric vehicles" i.e. will we change ?

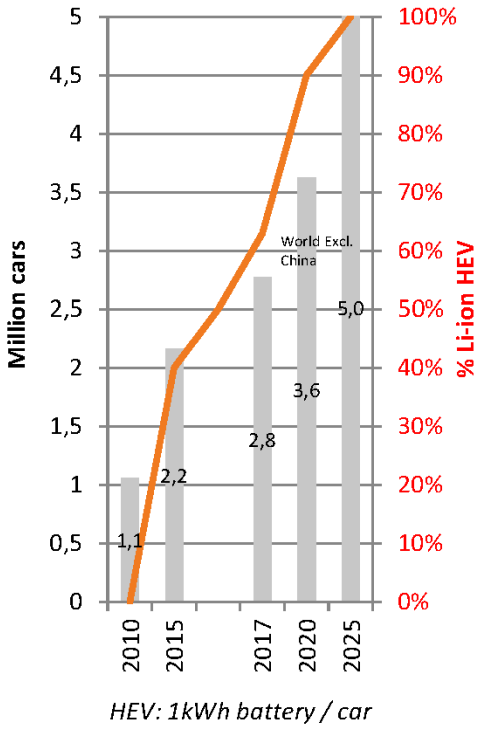
HEV, P-HEV, EV 2025 FORECASTS

HEV = Hybrid

PHEV= Plug in Hybrid

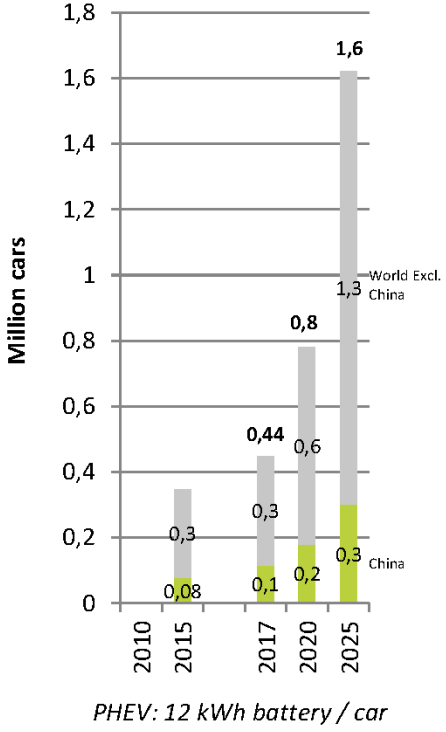
EV= Electric

HEV manufactured



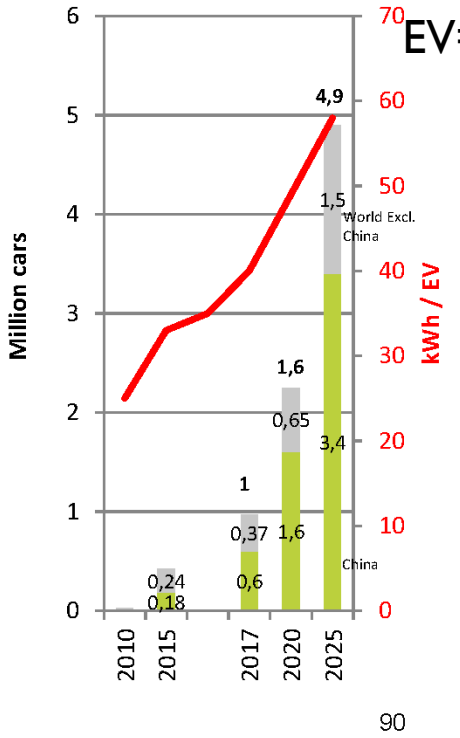
HEV: 1kWh battery / car

PHEV manufactured



PHEV: 12 kWh battery / car

EV manufactured



Estimated # cars on planet ~2025: 1.7 billion; XEV vehicles ~11 million is about 0.6%

Progress is slow

From talk by C.Pillot; Avicenne Energy; AABC, June 2018

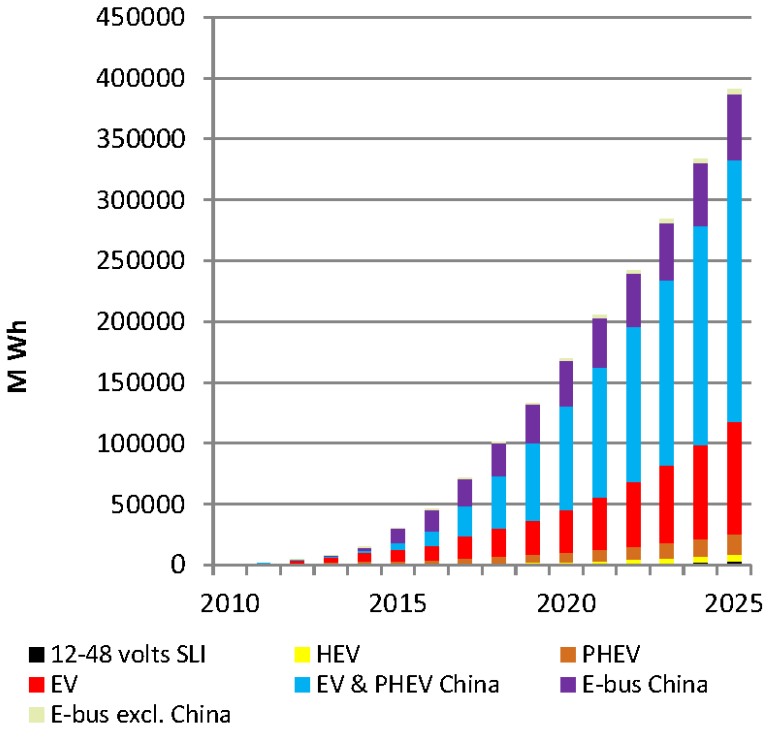
Battery demand by HEV, PHEV and EV's.

BATTERY DEMAND - XEV 2025 FORECASTS

China leads the world

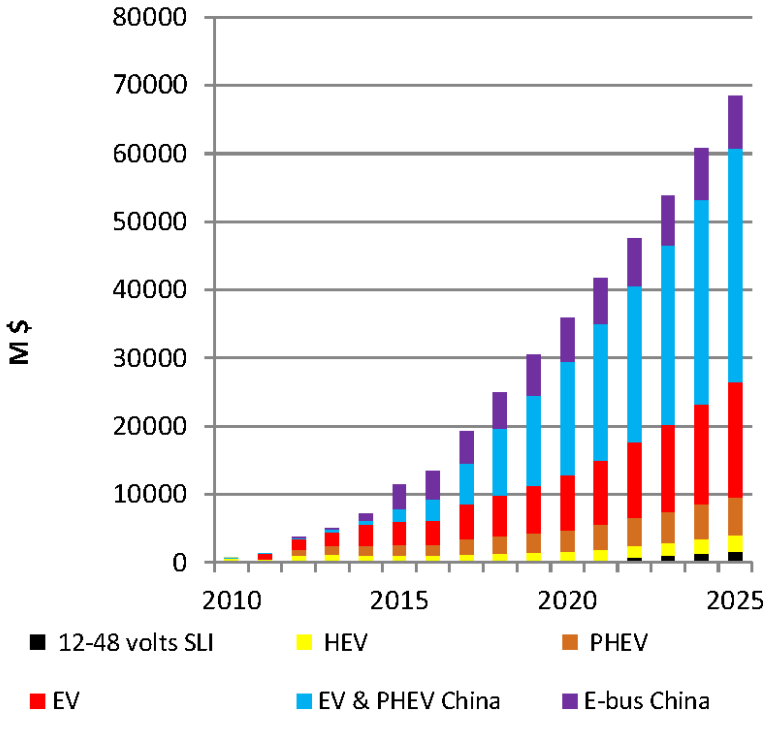
Li-ion for EV, HEV & P-HEV Battery needs (MWh)

CAGR 2017-2025: +24%



Li-ion for EV, HEV & P-HEV Battery needs (M$)

CAGR 2017-2025: +17%



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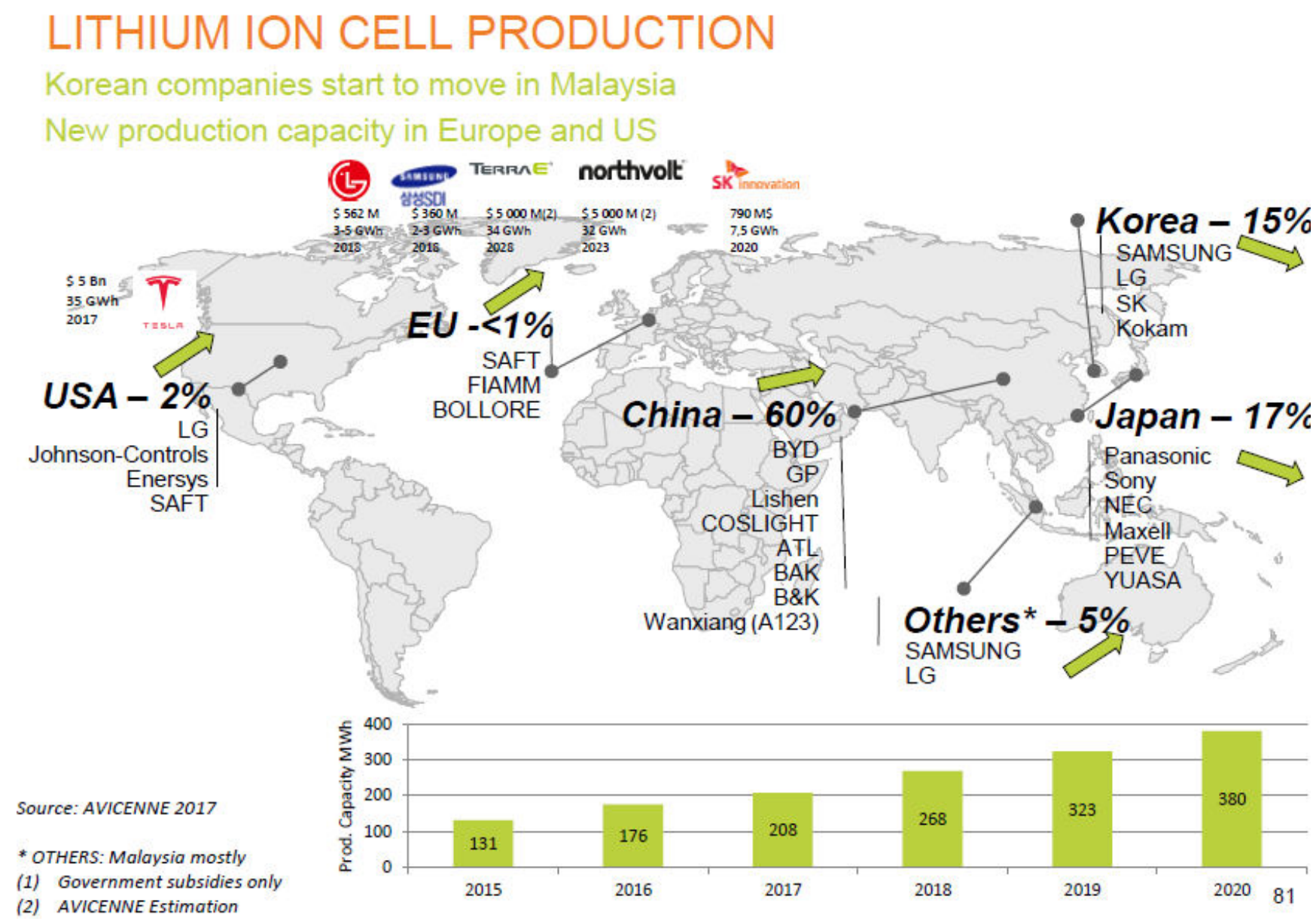
From talk by C.Pillot; Avicenne Energy; AABC, June 2018

Production of LIB across the world



Energy system

Changes in our energy system going away from fossil fuel are sloooow.

- Changes are slowed down by fact that large investments are needed and companies/economy is doing well using fossil fuel.
- Large reluctance to change when things are still working……and $'s flow
- This is not a mater of R&D, but willingness to change

Example China: forced to change because of extreme pollution; government has identified the problem

- May be in the end we will run out of fossil fuel and that will cause the world to act.
- There seems to be plenty of energy from the sun available to fulfill the planets needs, but needs a different infrastructure (not done that exercise)

Ironic: sun energy is from fusion; a process we have not mastered yet on earth

The long term future

What does the SM tell us ?

People do not ask that question
for impact on our future

There are four forces (weak, electromagnetic, strong and gravity).
They are well understood by now… gravity may still have surprise

With our current knowledge (SM) it is clear that we are confined to planet earth.

So we better make it work
for long haul

Given what we know now:

- There is no space travel over long distances
- So far we are alone (scary to think we are the only ones; public lecture Monday)
- There is no magical new form of energy that can be tapped

In my lifetime:

A lot of technical innovation, understanding the world around us,
but no new radical fundamental breakthroughs or discoveries

A bit provocative…… but my time is limited

Not the end, but will stop here for today

Two more slides on Puerto Rico electric power system

The PR electric power system

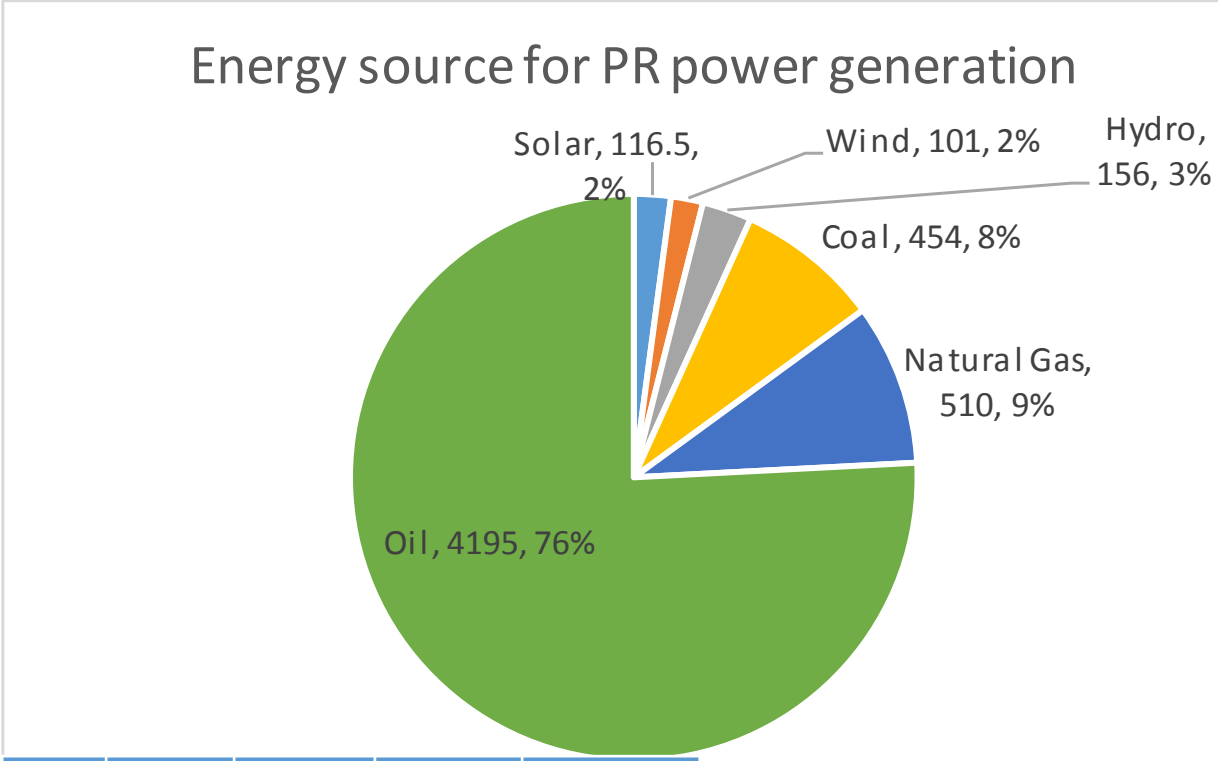
Status.pr gives the latest status on hurricane Maria recovery.
Electric system is at 95.2% (June 19, 2018)

We were lucky: water back in October and power back end of October 2017 (depends on community)

High level overview of electric power & grid.

- Total: 5.5 GigaW

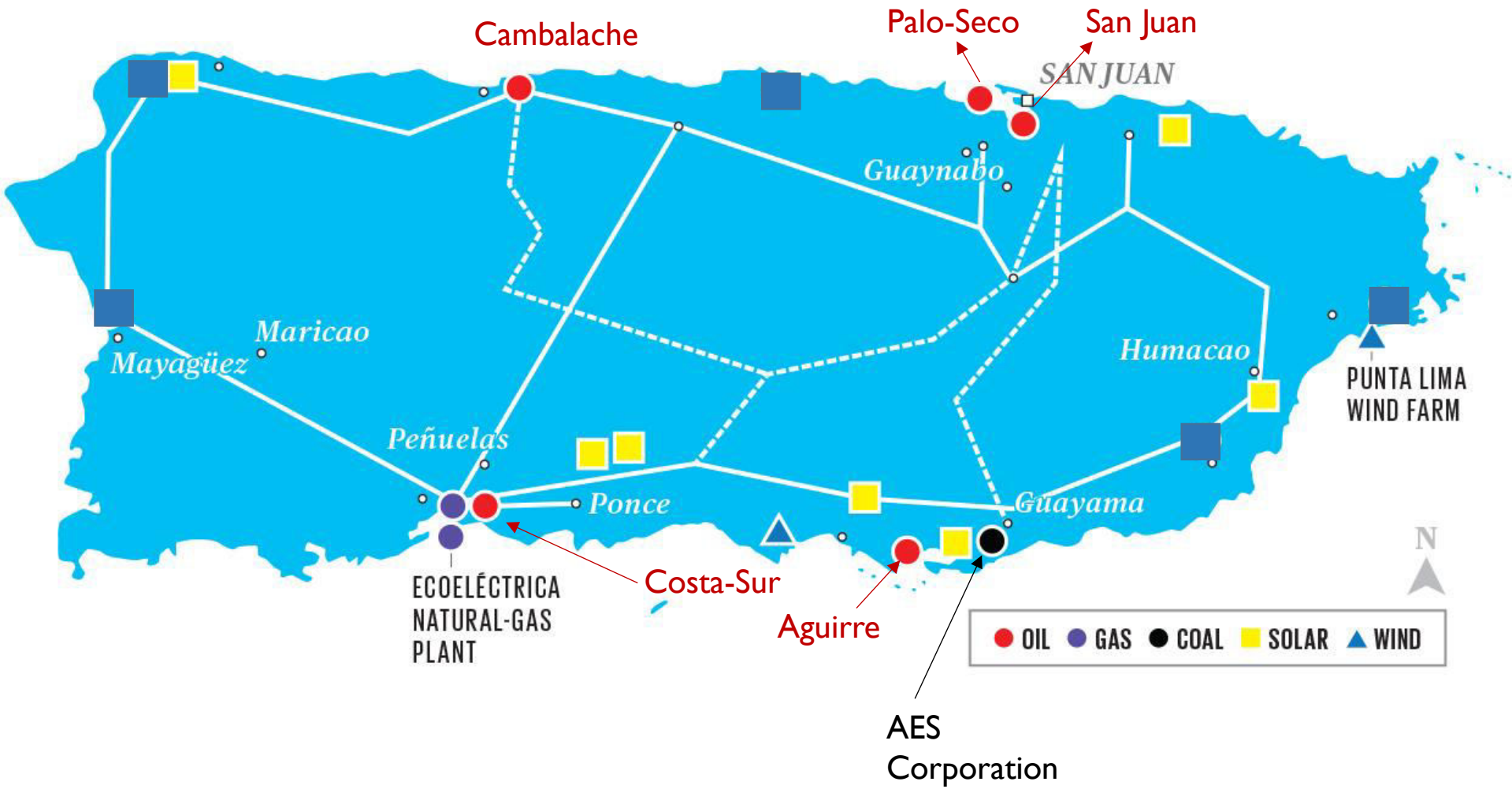
- All oil plants owned by utility
- All others by companies
- All fossil fuel is imported



Oil	LNG	Coal	Solar	Wind
5	1	1	5	2

plants

PR power plants & distribution -- geographically

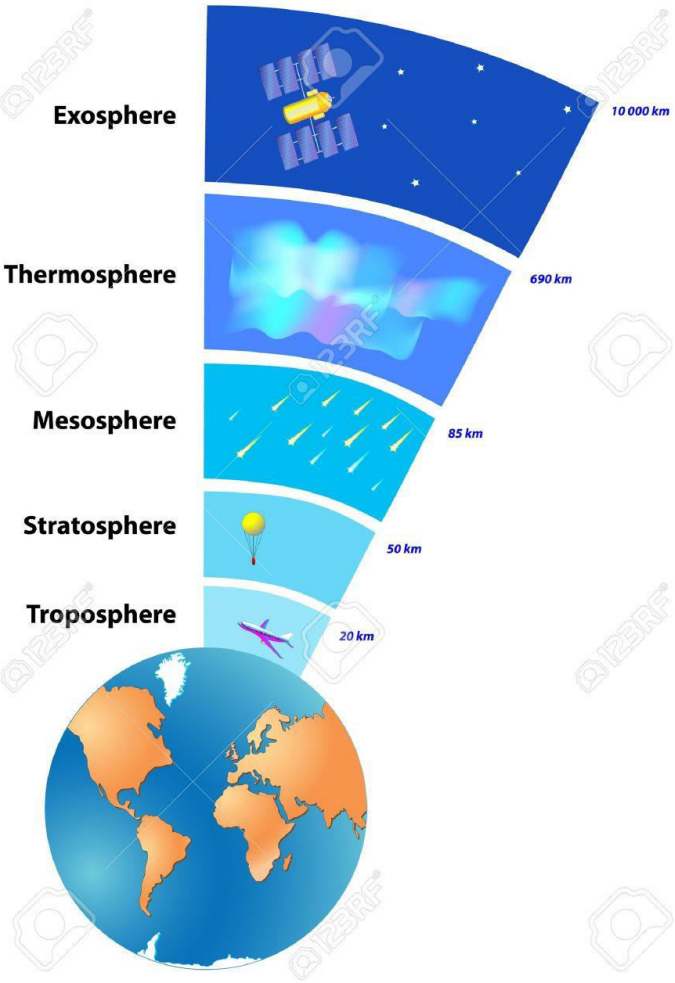


- Many power plants in south
- Transmission lines across mountains; vulnerable to environment & access only from air
- Recommendation for future: more local power generation/storage.
- Many people installing home solar & storage; independent of PREPA

END

Backup slides

Earth atmosphere



Composition of "air"

N2	O2	Ar	other
78.09%	20.95%	0.93%	0.04%

Troposphere varies from 9 km at poles to 17 km at the equator.

Total mass of atmosphere:
50% is below 5.6 km
90% is below 16km
99.99997% is below 100 km

Density drops by 50% roughly every 5.6km

In our model we assume it is uniform up 10 km. Probably too high.

If it had a uniform density (equal to sea level), it would be 8.5km high.

Better value for height

Price of LIBs

avicenne ENERGY
INFORMATION FOR GROWTH
www.avicenne.com

The Rechargeable Battery Market and Main Trends 2017 – 2025

18th Annual advanced automotive battery conference
June 4-7, 2018 • Hotel Del Coronado, San Diego, CA

San Diego

June 4th, 2018

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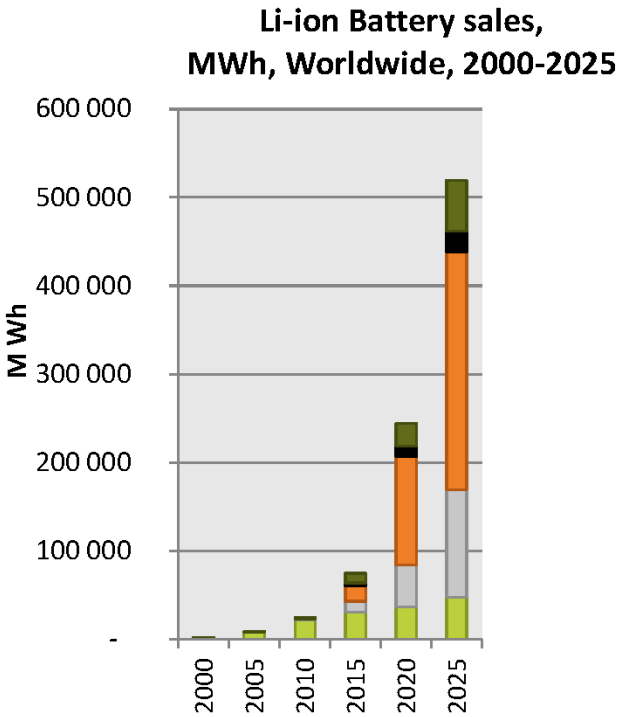
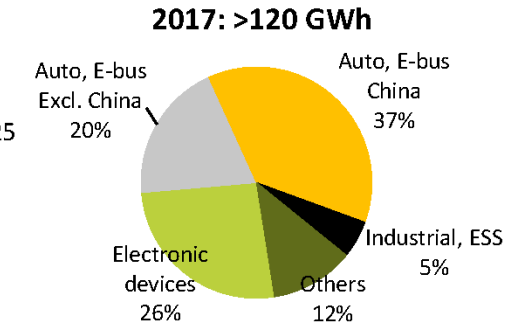
LI-ION BATTERY MARKET FORECASTS

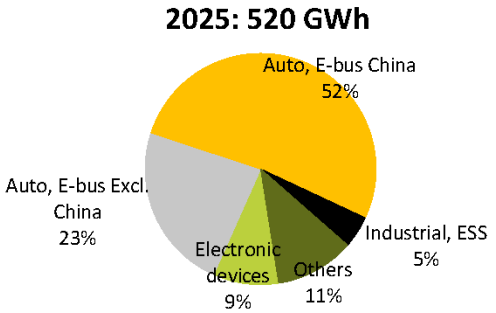
From 120 GWh in 2017 to 520 GWh

CAGR 2017/2025
+21 % per year in Volume



	CAGR 15/25 (Realistic)
Others	18%
Industrial, ESS	23%
Auto, E-bus China	31%
Auto, e-bus Excl. China	25%
Electronic devices	5%



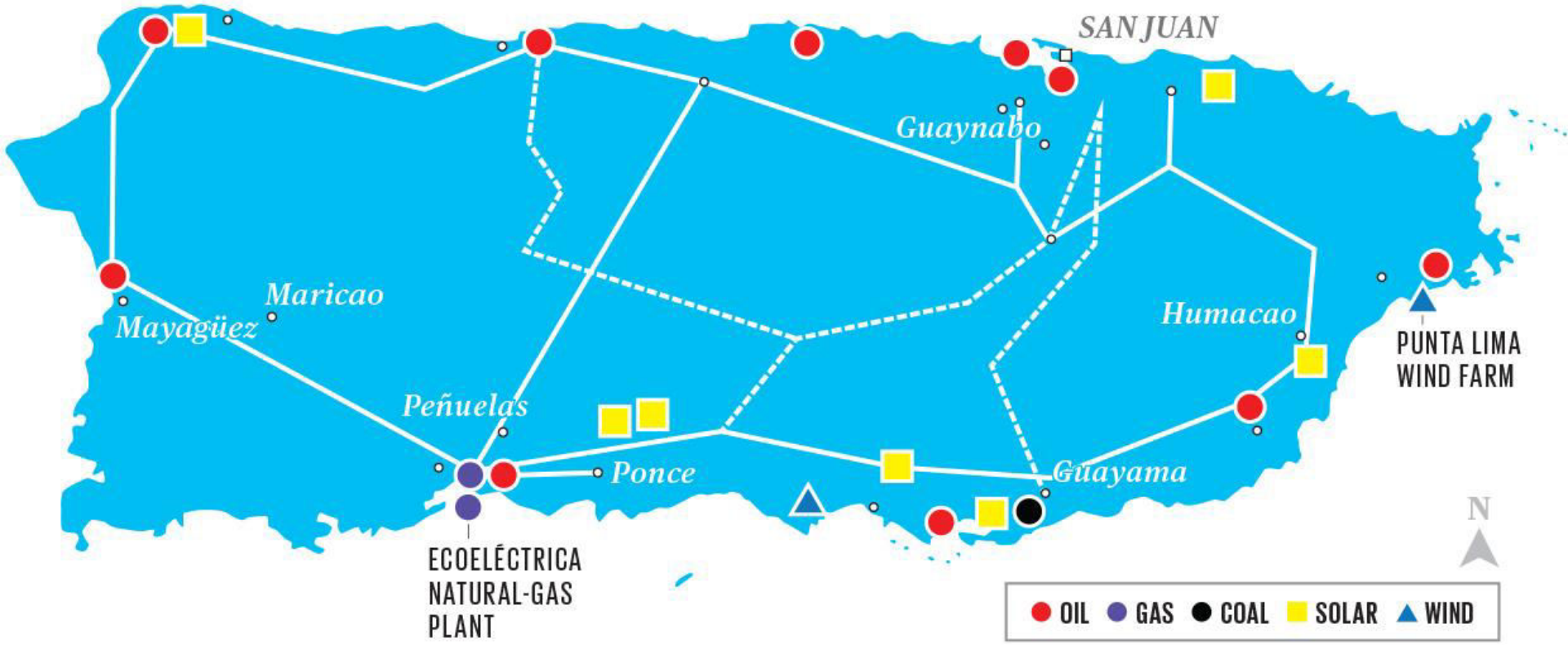


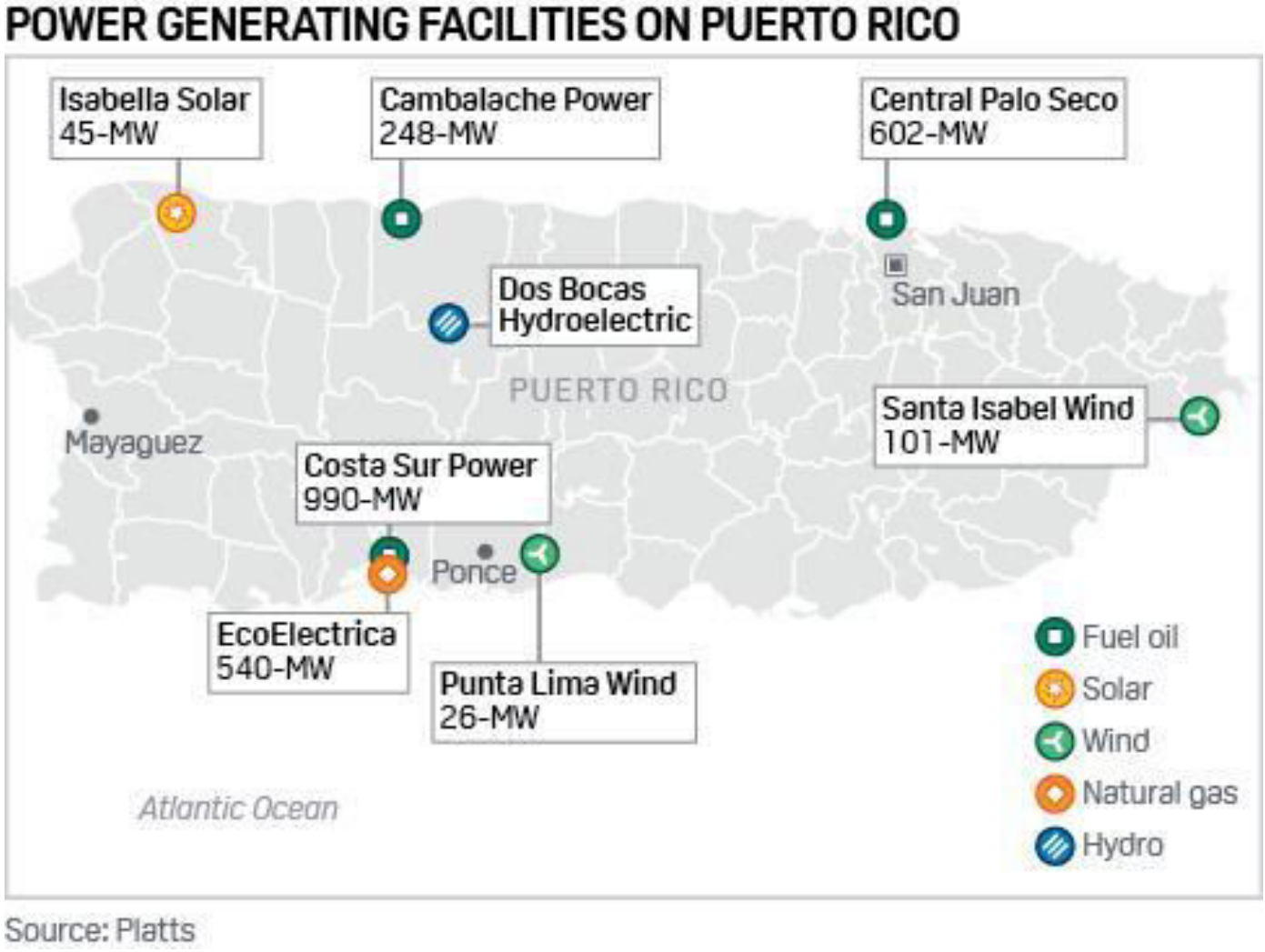
Others: medical devices, power tools, gardening tools, e-bikes…

Source: AVICENNE Energy 2018

Acknowledge C.Pillot

This map has a problem: the red dots are not just power plants, they seem to grid nodes. There is no oil power plant in Mayaguez or Isabela.





This map has a lot of information missing, like all the AES plants in Guayama.

The end

Always interested in technology…… cars, electronincs, computers

Able as a student to work on this….

Also interested in solving problems….. Not created by humans, but posed by nature

These things have been very imporstant in my life; main reasons for chosing experimental physics as direction