Engineering:

Not just your mind, it is part of your heart as well!

Mark J. McCready

Professor of Chemical and Biomolecular Engineering

Senior Associate Dean for Research and Graduate Studies

College of Engineering

http://www.chemeprof.com/

Outline

- Provide motivation for the "need" of engineers by society

- Give some insight into what "engineering" is as a profession and as an academic major

- Raise some issues that you may want to consider as you are deciding what to do in your future

- Some discussion of different engineering disciplines

http://www.chemeprof.com/

Why be an Engineer?

- Why am I an engineer?

http://www.chemeprof.com/

Why be an engineer?

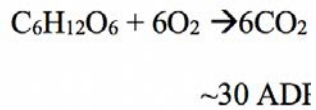When I taught a "... students that I co... cool if they were ... calculations

change. Dinosaurs as shown in Jurassic

ght!

Introduction:

Gigantism in dinosa...
it is hard to understa...
of stress that the ske...
the creature's own ...

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2$

~30 ADF

$$\frac{\partial T(x,t)}{\partial t} =$$

$$T(x,t) = \frac{2}{\displaystyle\sum_{j=}}$$

t=.5s
t=1s
t=2s
t=5s
t=10s

distance, m

3   1.0
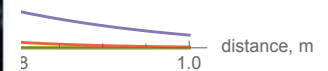
A lot of humans could have outrun Tyrannosaurus Rex and certainly escaped in a car CREDIT: GETTY CREATIVE
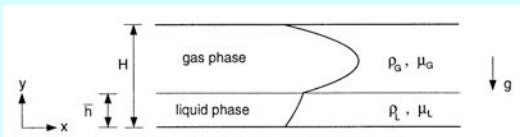
...meprof.com/

Why am I an engineer?

- https://www.youtube.com/watch?v=1-JdqHxqkHA

-

http://www.chemeprof.com/

Mathematical modeling can be complex

Geometry of interest

We will look at the linear stability problem for
- Steady flow
-
- Purely Oscillatory (Couette flow)

Gas-liquid flow interfacial stability problem
turbulence model: k-ε
Solve the base state with either a smooth or rough interface (try to match data).
then
Solve the differential stability problem the best we can

Stability equations continued

Stability equations continued

k=1 (liquid-phase) $0 \le y \le 1$
k=2 (gas-phase) $1 \le y \le n_2 + 1$

Stability Equations cont.

Boundary conditions

$(3\text{-}18c)$
$(3\text{-}18d)$
$(3\text{-}18e)$
$(3\text{-}18f)$
$(3\text{-}18g)$
$(3\text{-}18h)$

Figure 4.9   Basestates for horizontal air-water channel flow, d=2.54 cm, μ_L=1 cp. Gas phase is *turbulent* for all calculations.

We do these using computers it wasn't always this way!

http://chemeprof.com/

6

chemeprof.com/

Why be an engineer?

- https://www.youtube.com/watch?v=JVKK4QxWSNo

These examples demonstrate that engineering combines knowledge of the basic physical (chemical, biological) laws with mathematical analysis.

We endeavor to (and it is essential) that we use these calculations to <u>predict</u> how a device, system or phenomena will behave — before it is built!

There can be quite a bit of creativity in engineering — perhaps in deciding what "question" to ask or which problem to solve.

Many of these problems have a large impact on society!

http://www.chemeprof.com/

Why be an engineer?

Gene Therapy Hits a Peculiar Roadblock: A Virus Shortage

Nov. 27, 2017

Laboratory technicians working with viral vectors used in gene therapy. Custom-made viruses, required to insert good genes into cells, are in short supply.Phanie/Science Source

First CTE diagnosis on living NFL player confirmed by autopsy, report shows

Fox News
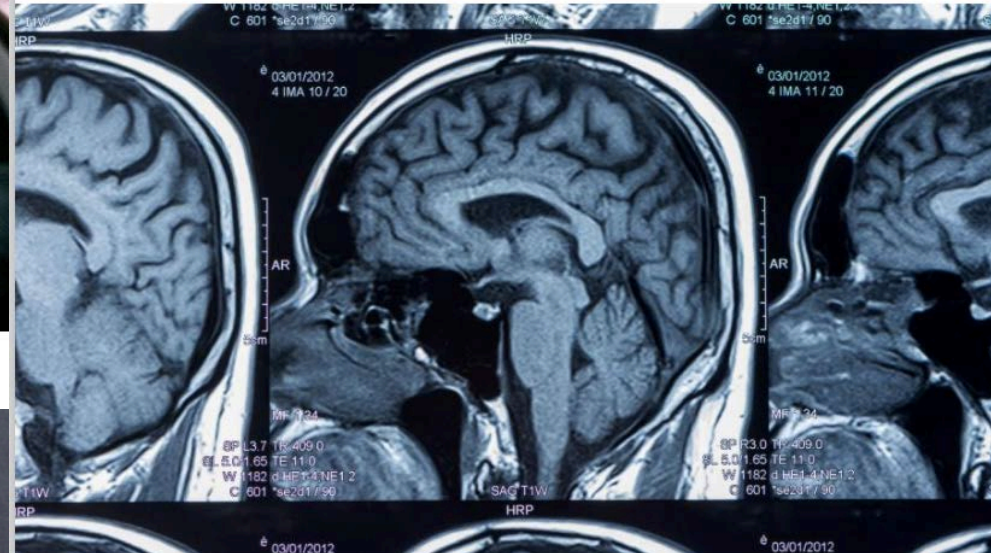
A medical breakthrough in CTE research on NFL players

A new report shows doctors have accurately diagnosed a living former NFL player with chronic traumatic encephalopathy (CTE). How could these new findings help early detection and treatment?

8

http://www.chemeprof.com/

Why be an engineer?

PERSONAL HEALTH

Unlocking the Secrets of the Microbiome

Paul Rogers

By Jane E. Brody

Nov. 6, 2017

f 🐦 ✉ ➤ 🔖 [105]

Modern technology is making it possible for medical scientists to analyze inhabitants of our innards that most people probably would rather not know about. But the resulting information could one day save your health or even your life.

This is a "systems" problem as much as a biological problem.

How can we keep track of and interpret all of the biological data!

http://www.chemeprof.com/

Why be an engineer?

- Sometimes we fail

- We can't let this happen again!

http://www.chemeprof.com/

Why be an engineer?

The New York Times

F.D.A. Approves First Gene-Altering Leukemia Treatment, Costing $475,000

A technician working with human cells belonging to cancer patients at Novartis Pharmaceuticals in Morris Plains, N.J. The Food and Drug Administration on Wednesday approved Novartis's gene therapy for leukemia, the first-ever treatment that alters a patient's own cells to fight cancer. Brent Stirton/Novartis Pharmaceuticals Corp., via Associated Press

A massive challenge will be scaling up. Currently, each patient requires a team of highly trained, specialized scientists and technicians to re-engineer his T-cells. "If you have 100,000 lung-cancer cases each year, there aren't 100,000 Ph.D.s to grow the cells," Dr. June says. "So it needs to be done with robotics."

No, Actually, probably clever chemical engineering!

http://www.chemeprof.com/

What engineering calculations are most relevant?

Diesel fumes make British streets among most toxic in West

Chris Smyth, Health Editor

October 20 2017, 12:01am,
The Times

Britons are about twice as likely to die from pollution as people in Sweden, New Zealand, Australia, Canada and Ireland, with diesel vehicles being blamed

GETTY IMAGES

👁 Let's do electric cars!

COMPANY NEWS   MAY 27, 2018 / 8:52 AM / 23 DAYS AGO

UPDATE 4-Thousands evacuate as Storm Alberto powers toward Florida

Reuters Staff   4 MIN READ   🐦 f

(Adds latest movements of storm, Maryland flooding)

By Jon Herskovitz

May 27 (Reuters) - Thousands of Florida residents evacuated homes on Sunday as

It is 351 miles from Miami to Jacksonville.
This is 1 tank of gas for a IC car.
This is 5 hours of driving on 3 minutes of fueling time, ~1% downtime.

Best current generation electric car:
75 minutes to change to 335 miles, ~27% downtime!

The range of most electric cars is even less so that it would not have been possible to "evacuate the state" if everyone was using an electric car!

http://www.chemeprof.com/

Definitions of engineering

en·gi·neer [en-juh-neer] ? Show IPA
Dictionary.com Unabridged

noun

1. a person trained and skilled in the design, construction, and use of engines or machines, or in any of various branches of engineering: *a mechanical engineer; a civil engineer.*

engineering
Use **Engineering** in a sentence

en·gi·neer·ing [en-juh-neer-ing] ? Show IPA

noun

1. the art or science of making practical application of the knowledge of pure sciences, as physics or chemistry, as in the construction of engines, bridges, buildings, mines, ships, and chemical plants.
2. the action, work, or profession of an engineer.
3. skillful or artful contrivance; maneuvering.

Origin:
1710–20; engineer + -ing[1]

en·gi·neer·ing
/ˌenjəˈni(ə)riNG/

noun
noun: engineering

the branch of science and technology concerned with the design, building, and use of engines, machines, and structures.

- the work done by, or the occupation of, an engineer.
- the action of working artfully to bring something about.
  "if not for Keegan's shrewd engineering, the election would have been lost"

en·gi·neer
/ˌenjəˈni(ə)r/

verb
gerund or present participle: **engineering**

design and build (a machine or structure).
"the men who engineered the tunnel"

- skillfully or artfully arrange for (an event or situation) to occur.
  "she engineered another meeting with him"
  synonyms: bring about, arrange, pull off, bring off, contrive, maneuver, manipulate, negotiate, organize, orchestrate, choreograph, mount, stage, mastermind, originate, manage, stage-manage, coordinate, control, superintend, direct, conduct; More
- modify (an organism) by manipulating its genetic material.
  "genetically engineered plants"

en·gi·neer·ing *noun* \-'nir-iŋ\

: the work of designing and creating large structures (such as roads and bridges) or new products or systems by using scientific methods

: the control or direction of something (such as behavior)

Full Definition of ENGINEERING   Cite! g+1 Like

1 : the activities or function of an engineer

2 a : the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people

   b : the design and manufacture of complex products <software *engineering*>

3 : calculated manipulation or direction (as of behavior) <social *engineering*> — compare GENETIC ENGINEERING

   See engineering defined for English-language learners »
   See engineering defined for kids »

http://www.chemeprof.com/

What do engineers do?

- Or, you may have heard it stated that "engineers solve problems..."

- What engineers really do is:

- *Engineers understand how to use techniques of <u>engineering analysis</u> to design (i.e., synthesize) substances, devices and processes even though they have an <u>imperfect</u> <u>understanding</u> of important physical, chemical or biological issues. Furthermore engineers operate under <u>constraints</u> caused by a need to produce a product or service that is timely, competitive, reliable, and consistent with the philosophy and within the financial means of their company.*

- *We need to use <u>all</u> that we know to produce the <u>best answer </u>to a problem!!*

Underlined words

- 1. Engineering analysis

- Engineers use "mathematical models" to describe reality in sufficient detail to produce quantitative results.

- (It is not engineering until we produce some numbers!!)

Underlined words

- 2. Imperfect understanding

- Most significant engineering problems cannot be analyzed and solved exactly.

-

- Thus we need our models or our understanding of phenomena gained by experiment to capture the important features and (usually) ignore a lot of unessential detail.

Curveball vs. knuckle ball

- We tried to make the argument that the imperfectness of a baseball is important to the pitching of a knuckleball, which does not spin and not important in the pitching of a curveball which spins fast. The same effect can either be important or incidental. This is because important issues always as ratios between competing effects. Engineers need to make the decision about what is important!!

Mathematical Analysis

- We would like to know how a device, process or system behaves "before" we build it

- The only way that this is possible is with accurate mathematical "models" (collections of mathematical equations, that could be based on physical laws or verified observations that represent **reality** sufficiently well)

Engineering

- Engineers seek to develop technologies that make the world a better place for humanity!

    - There are elements of creativity involved

- However, we need to realize there are limitations...

    - The laws of nature!

http://www.chemeprof.com/

Physical Laws

$$\mathbf{F} = \frac{d\mathbf{p}}{dt} = \frac{d(m\mathbf{v})}{dt}.$$

he second law can also be stat

$$\Delta U = Q + W$$

$$dS > \frac{\delta Q}{T}$$

Differential equations

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \left(\mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right)$$

Incompressible Navier–Stokes equations (*convective form*)

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\mathbf{u} - \nu \nabla^2 \mathbf{u} = -\nabla w + \mathbf{g}.$$

Deflection at Any Given Point

$$y = \frac{Wx(l-x)}{24EIl}[l^2 + x(l-x)]$$

http://www.chemeprof.com/

Different engineering disciplines

- Mechanical: $\mathbf{F} = \dfrac{d\mathbf{p}}{dt} = \dfrac{d(m\mathbf{v})}{dt}$ other classic laws... generally a macroscopic view of the world and an interest it detailed workings of devices

  - "Glory job": Robots, making everything <u>work</u>

- Electrical: $\nabla \cdot \mathbf{E} = \dfrac{\rho}{\varepsilon_0}$ detailed and somewhat abstract view of the world

  - Glory job: Streaming 4K video to your phone

<u>http://www.chemeprof.com/</u>

Different engineering disciplines

- Civil: $y = \frac{Wx(l-x)}{24EIl}[l^2 + x(l-x)]$ + other classic laws... generally a macroscopic view of the world

  - "Glory job": Building large structures and supporting the civil infrastructure

- Chemical:

  Rectangular (x, y, z, t)

  $$\frac{\partial C_i}{\partial t} + v_x \frac{\partial C_i}{\partial x} + v_y \frac{\partial C_i}{\partial y} + v_z \frac{\partial C_i}{\partial z} = D_i \left[\frac{\partial^2 C_i}{\partial x^2} + \frac{\partial^2 C_i}{\partial y^2} + \frac{\partial^2 C_i}{\partial z^2} \right] + R_{Vi}$$

  - + chemistry

  - detailed, molecular bridging up to macro scale but possibly, (abstract) view of the world

  - Glory job: Making Pharmaceuticals.. and... all of the "stuff"

http://www.chemeprof.com/

Different engineering disciplines

- Biological/biomedical:

$$\frac{d[\mathrm{P}]}{dt} = k_{\mathrm{cat}}[\mathrm{E}]_0 \frac{[\mathrm{S}]}{K_{\mathrm{M}} + [\mathrm{S}]}.$$

Eukaryote — Pr

Membrane-enclosed nucleus — Mitochondrion

Nucleolus — Ribosomes

Cell Membrane

A **eukaryotic** cell (left) and a (right)
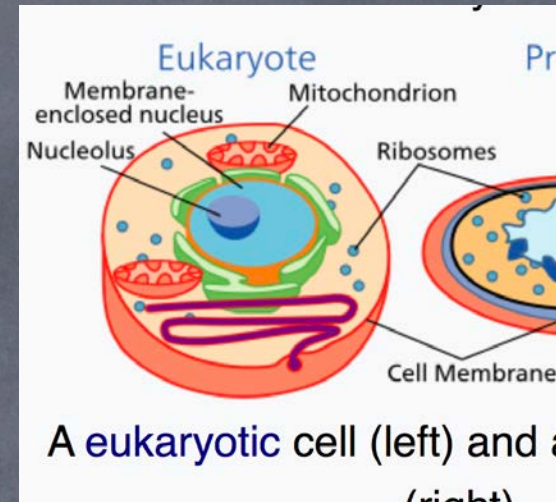
$$\Delta U = Q + W$$

Rectangular (x, y, z, t)

$$\frac{\partial C_i}{\partial t} + v_x \frac{\partial C_i}{\partial x} + v_y \frac{\partial C_i}{\partial y} + v_z \frac{\partial C_i}{\partial z} = D_i\left[\frac{\partial^2 C_i}{\partial x^2} + \frac{\partial^2 C_i}{\partial y^2} + \frac{\partial^2 C_i}{\partial z^2}\right] + R_{V_i}$$

$$\mathbf{F} = \frac{d\mathbf{p}}{dt} = \frac{d(m\mathbf{v})}{dt}$$

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

- Detailed, on the level of cells, but otherwise integrative view of the world

- "Glory jobs": Replacement limbs and joints, replacement organs, targeted treatments

24

http://www.chemeprof.com/

Majoring in Engineering at a University

- In the spirit of "truth in advertising", "Engineering" as a college major is an intense intellectual experience.

- Engineers need to provide the exact design specifications for all of the technologies.

- Hence we spend a lot of time teaching you how to do calculations and to get the numbers correct

  - Professors give "lectures" about what you need to understand

    - Some of the topics are completely new!

- You go off and read, do homework (usually with your friends) and "study".

- We then have a "test" to find out how much you learned!

25

http://www.chemeprof.com/

Do we already know everything?

- You might say…

    - "Maybe there is little that I could contribute."

- Over the years, many claims of certainty have proven to be completely wrong!

http://www.chemeprof.com/

It is OK to challenge accepted thinking!

- Some things we thought we knew:

    - Margarine was considered a health food

    - Left-handed people die sooner because of the hazards of the right-handed word

    - Stomach Ulcers are caused by stress

    - Plants absorb CO_2 and emit O_2

    - The adult brain has no capacity to regenerate itself

    - Komodo Dragons bit their prey and waited for them to succumb to bacterial infections

http://chemeprof.com/

chemeprof.com/

SOME DOUBT BUT...

The Diet-Heart Myth: Cholesterol and Saturated Fat Are Not the Enemy

on **APRIL 19, 2013**   by **CHRIS KRESSER**   **619** *comments*

How did we come to believe saturated fat and cholesterol are bad for us?

17 JUL

325

CHOLESTEROL IS NOT BAD FOR YOU

Home > Blog > Cholesterol is not bad for you

Published on: Wednesday, 27 May, 2015

A sixty-year torrent of bad dietary advice is coming to an end

My Times column on the U-turn over cholesterol and saturated fat:

Cholesterol U-turn as research shows fatty foods might not be bad for us after all

Doctors are now focusing on sugar as the biggest danger to public health

SOME DOUBT?

The U.S. government is poised to withdraw longstanding warnings about cholesterol

By **Peter Whoriskey** February 10, 2015

Time to put eggs back on the menu? (Deb Lindsey for The Washington Post)

Most Read

1 The world's losers are revolting, and Brexit is only the beginning

2 The British are frantically Googling what the E.U. is, hours after voting to leave it

3 Brexit is a reminder that some things just shouldn't be decided by referendum

4 California may have a huge groundwater reserve that nobody knew about

5 Ginsburg smacks down a major abortion myth after historic SCOTUS ruling

LOW FAT?

Four reasons "fat-free" isn't good for you

on MARCH 18, 2013   by LIFE WITH GREENS   in MISLEADING MONDAYS   27

The truth about low-fat foods

Kerry Torrens

Low fat foods stuffed with 'harmful' levels of sugar

SALT?

Go to Well Home

Well

HEART

A Low-Salt Diet May Be Bad for the Heart

By NICHOLAS BAKALAR   MAY 25, 2016 1:45 PM   💬 69

🏷 **TAG**   Salt , sodium , Salt intake , Diet , Medical Controversy

Low-Salt Diet Bad For Your Heart? Not So Fast!

22 May 2016, 5:02 am EDT   By James Maynard Tech Times

FOR SURE?

MAY 19, 2015 @ 09:53 AM   992,226 VIEWS   The Little Black Book of Billionaire Secre

Updated NASA Data: Global Warming Not Causing Any Polar Ice Retreat

James Taylor, CONTRIBUTOR
I write about energy and environment issues. **FULL BIO** ∨
Opinions expressed by Forbes Contributors are their own.

Updated data from NASA satellite instruments reveal the Earth's polar ice caps have

T D B	Yahoo	A cost curve for greenhouse gas red...	Robert Gordon: The death of innovat...	Could Extremely Low-Calorie

NASA · Topics | Missions | Galleries | NASA TV | Follow NASA | Downloads | About | NA

Latest | Related

Ice

NASA's Operation IceBridge Completes 2016 Arctic Spring...
22 days ago

Clouds and Sea Ice: What Satellites Show About Arctic Climate Change
25 days ago

NASA Studies Details of a Greening Arctic

Oct. 30, 2015

NASA Study: Mass Gains of Antarctic Ice Sheet Greater than Losses

A new NASA study says that an increase in Antarctic snow accumulation that began 10,000 years ago is currently adding enough ice to the continent to outweigh the increased losses from its thinning glaciers.

32

MUCH OF WHAT IS BEING PUBLISHED IS PROBABLY NOT CORRECT!

Essay

Why Most Published Research Findings Are False

John P. A. Ioannidis

Over half of psychology studies fail reproducibility test

Largest replication study to date casts doubt on many published positive results.

Monya Baker

ESSAY

Why Most Clinical Research Is Not Useful

John P. A. Ioannidis[1,2]*

Studies show only 10% of published science articles are reproducible. What is happening?

Posted on May 3, 2012 by Moshe Pritsker

Studies show a very low reproducibility for articles published in scientific journals, often as low as 10-30%. Here is a partial list:

EVEN THE TEMPERATURE? (YIKES!)

Earth is warming 50x faster than when it comes out of an ice age

A major new study includes some scary implications about how rapidly humans are changing the Earth's climate

ᵀᴴᴱ DAILY CALLER NEWS FOUNDATION

Scientists Finally Admit Climate Models Are Failing To Predict Global Warming

Committee of the U.S. House of Representatives on December 8.

/26/2

Global Bulk Atmospheric Temperature (Surface-50K ft)

Average of 102 IPCC CMIP-5 Climate Model runs

Observations
Circles - Avg 4 Balloon datasets
Squares - Avg 3 Satellite datasets

The linear trend (based on 1979-2014 only) of all time series intersects at zero at 1979

JR Christy. Univ. Alabama in Huntsville
Model output: KNMI Climate Explorer
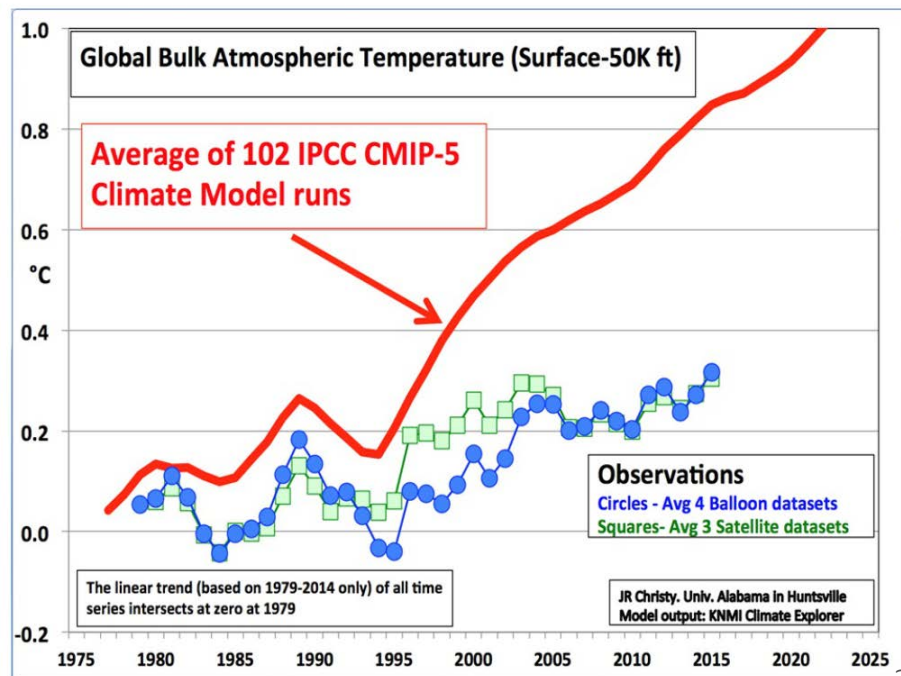
Quantifying climatic variability in monsoonal northern China over the last 2200 years and its role in driving Chinese dynastic changes

Jianyong Li [a,*], John Dodson [a,b,**], Hong Yan [a,***], David D. Zhang [c], Xiaojian Zhang [d], Qinghai Xu [e], Harry F. Lee [c], Qing Pei [f], Bo Cheng [g], Chunhai Li [h], Jian Ni [i], Aizhi Sun [j], Fengyan Lu [a], Yongqiang Zong [k,l],

[a] State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710075, China

North China

Age (AD)

Li et al., 2017

34
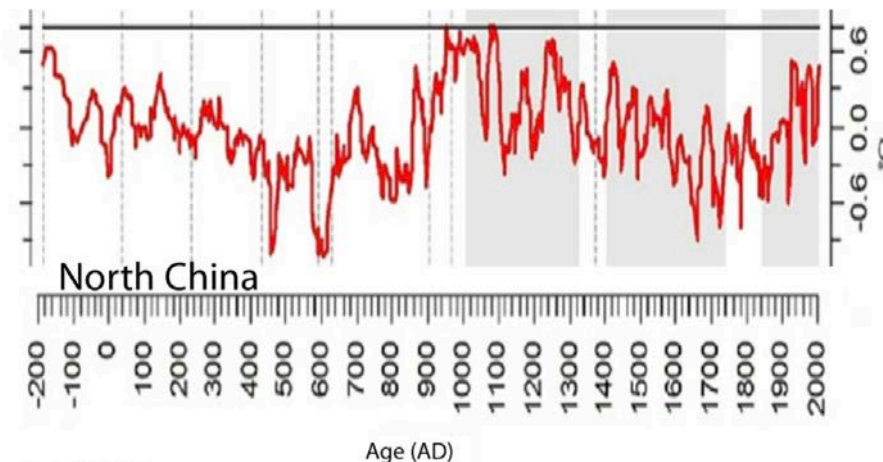
WE NEED YOU!

- Desperately!

Significant Progress

- Gas mileage doubled since 1972

Significant Progress

- Fuel use per passenger mile is about 30% of original passenger jets

http://chemeprof.com/

chemeprof.com/

Success to date

1968   2005

http://www.chemeprof.com/

Some thoughts

- You will (soon) actually be in a position to make decisions on your own

  - some of which will determine your future path!

- It is possible that the issue of fulfillment is a bit complex:

  - You may have had discussions with your friends, and with yourself along the lines...

    - Should I try to make a lot of money?

    - Should I try to "save the world"?

http://www.chemeprof.com/

Major issues for Humanity

- Healthcare

- Energy

- The Environment

- The Economy

- Engineers are critically involved in all of these and will chart the future course

- "Society" may call these issues "problems", engineers see these as challenges to be met!

http://chemeprof.com/

40

chemeprof.com/

RECAP

- Engineering involves analyzing a specific device or system using mathematical analysis based on physical laws or empirical understanding

- All problems of real importance have some degree of uncertainty and so judgement is needed

- Many big questions remain and you can contribute to their solution

- You may find fulfillment in the problems of global importance that are being addressed by engineers!

http://chemeprof.com/

chemeprof.com/

Question about what do we have wrong?

- Trying to use "wind" and solar to replace fossil fuels for electricity generation.

http://www.chemeprof.com/

Challenges of renewable Energy

- Let's consider

  - Wind

  - Solar

  - Biomass

Wind

- Roughly, it takes 350-450 square miles of windmills (approximately 13000 wind turbines) to produce the electrical equivalent of a large coal or nuclear plant: 1000MW.

- This is the size of St. Joseph Co. IN

- 300,000 people live here and we use about 600 MW

- We don't have very good wind here (so it would not work) and it would seem a bit inconvenient to cover 1/2 of the county with windmills

http://chemeprof.com/

http://ndcbechair.blogspot.com/

To replace just the coal...

If You Want to Replace US Coal-fired Capacity with Wind, Then Find a Land Area the Size of Italy

Energy Density of Wind and solar

- If we work out the numbers, the power density of wind is about

  - 0.004 MW/acre

- What could we compare this to (Engineers always want to make comparisons!)

- How about solar flux?

  - We can capture only part of the solar flux for useful heat, much less for electricity

    - What are these numbers?

- Solar flux averaged over the earth is ~350 W/m^2

- While nothing more energetic than a tree "runs" directly on solar, this gives a value of about

  - 0.3 MW/acre

http://chemeprof.com/

25

http://ndcbechair.blogspot.com/

Energy Density of Ethanol from corn

- About 2.7 gallons of ethanol can be obtained from a bushel of corn

- Iowa can average about 160 bu/acre, which gives us about 400 gallons per acre

- This is about 1200 W/acre or 0.001 MW/acre

26

More about Ethanol?

- Ethanol, mostly from corn, provides about 1.5% of highway fuels in the US.

  - The cost is subsidized....

  - EtOH production from corn has a ERoEI that is estimated to range from .7 to ~1.3.

    - So ethanol may be an energy source, just not a very high density one.

  - There is no apparent pollution or green house gas benefit

  - There is not enough land area to greatly change the 1.5% number and there is definitely an effect on food prices

- Ethanol from cellulose would be a better alternative, but...

http://chemeprof.com/

http://ndcbechair.blogspot.com/

To get 20% of energy from biomass

From: Smaller, Faster, Lighter, Denser, Cheaper:How Innovation Keeps Proving the Catastrophists Wrong: Robert Bryce

Source: Author calculations, based on land-productivity calculations for biofuels published by Oak Ridge National Laboratory.

What Else to Compare

- 1000 MW power plant using coal might occupy 100 acres

  - This is enough power for 1 Million people in the US

- 1 really good oil well could produce 100,000 bbl/day

  - This is an equivalent amount of power

http://chemeprof.com/

29

http://ndcbechair.blogspot.com/

On a 100 acre Site:

- Coal to Electricity: 1000 MW

- Solar to Electricity: 30 MW

- Wind to Electricity: 0.4MW

- Corn to liquid fuel: 0.1 MW

- 10 oil wells (surface footprint): 10 GW

http://ndcbechair.blogspot.com/

Engineers like to compare things

- If I asked: ".. how far is it to Chicago?"

  - would you answer?

    - "a couple of hours" or...

    - "about 90 miles"

- If I asked: ".. is a meter a long distance?" what would you say

  - "No", compared to the distance to Chicago

  - "Yes", compared to a micron

- For our conclusion to be valid we need to

  - **compare** <u>like</u> (same dimensions) quantities.

<u>http://chemeprof.com/</u>

<u>chemeprof.com/</u>

POWER AND WIND SPEED?

- How does the power generated by the windmill change with wind speed?
  - How is power being generated?
    - Wind flows through area swept by blades
    - Windmill converts this kinetic energy to electric power

Air flow in

Air flow out

Power out
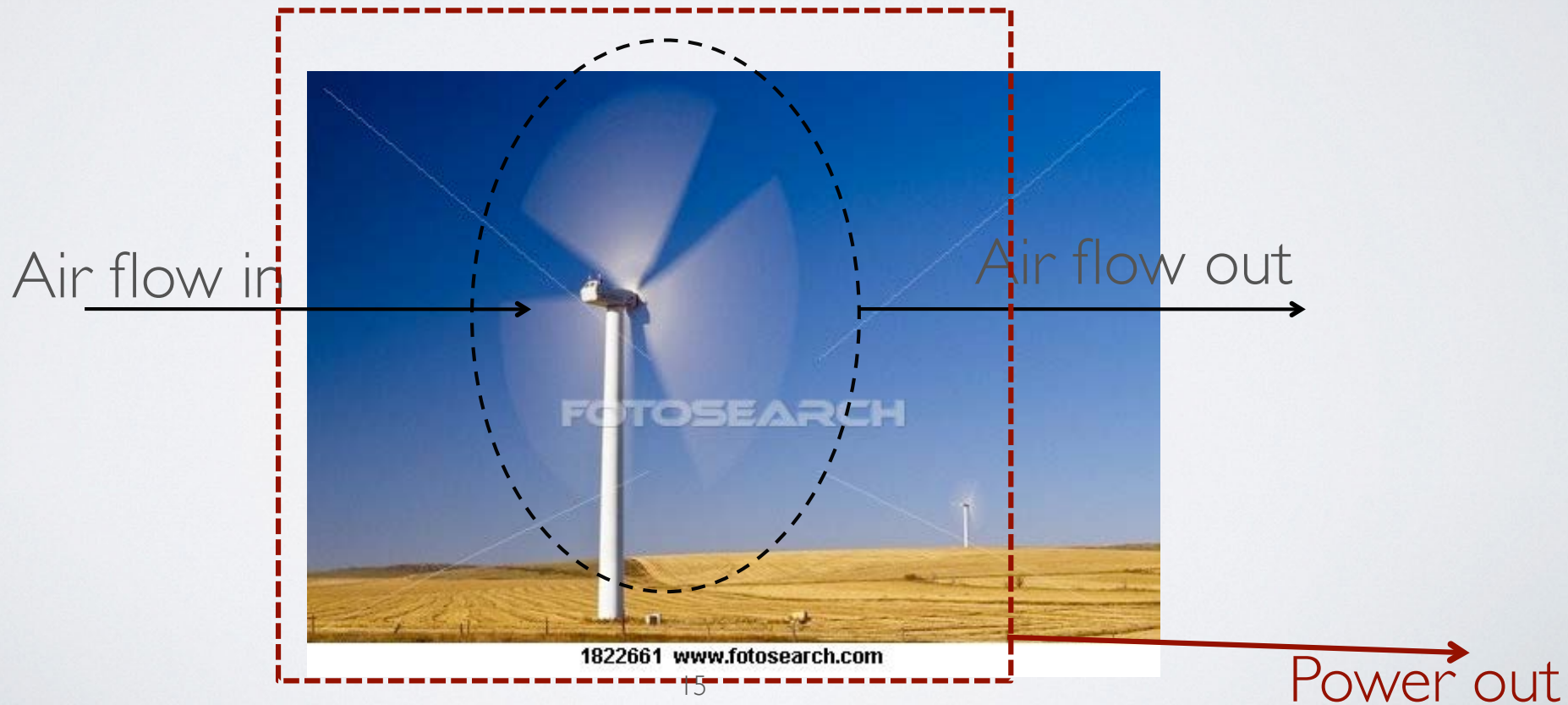
POWER AND WIND SPEED?

- How does the power generated by the windmill change with wind speed?
  - Let's see if we can figure this out based on dimensional reasoning
    - Power is work/time which is force * distance/time which is mass* acceleration *distance/time
    - Thus we could write

$$power = m \ l/t^2 l/t = \frac{ml^2}{t^3}$$

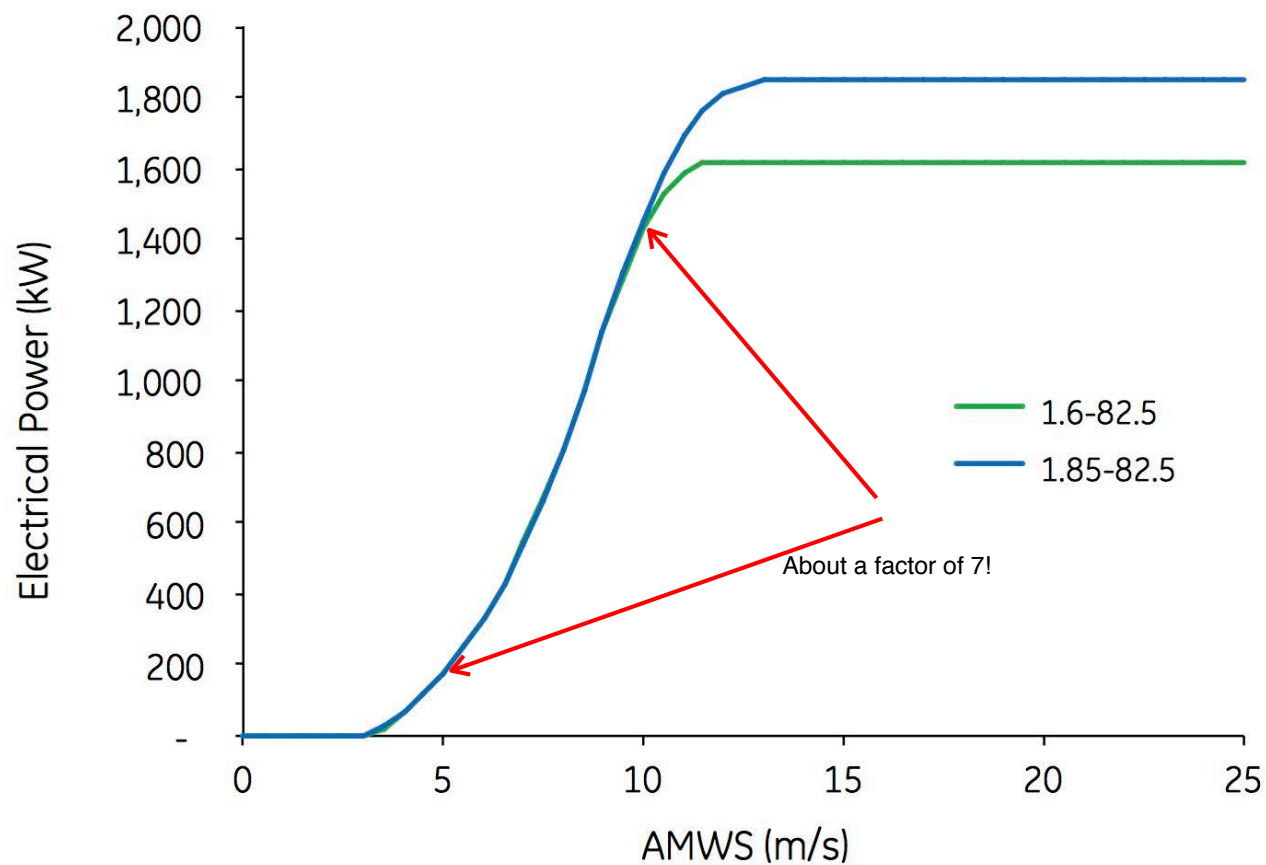 - What variables could be used?

EQUATION FOR POWER FROM WIND

- Windspeed, blade diameter, air density
  - v [=] l/t
  - d, r [=] l
  - Density of air ρ [=] m/l³
  - Arrange these variables to get dimensions of power:

$$power \sim \rho v^3 d^2 [=] \frac{ml^2}{t^3}$$

  - If the wind speed is cut in half, the power reduced to 1/8!
  - So our 40 wind turbines will produce about….
    - 7 MW!

WIND TURBINE POWER

Power Curve

Dimensionless Confucius Proverb

$$Cr \equiv \frac{How \; Smart \; You \; Are}{How \; Smart \; You \; Think \; You \; Are}$$

- He who knows not and knows he knows not is a child, teach him, Cr~1

- He who knows not and knows not he knows not is a fool, shun him, Cr<<1

- He who knows and knows not he knows is asleep, awaken him, Cr>>1

- He who knows and knows he knows is wise, follow him Cr~1

http://chemeprof.com/

42