

Making the future awesome: A Techno-Optimist's Perspective

APS 2021, Virtually in Denver CO

Ross Koningstein
Shaughnessy (Siri) Brennan Brown



A Post-Climate-Anxiety Future

Humanity has moved on to exciting new things because
climate is under control

Google Research

Image: Surface of Mars, NASA/JPL

A Post-Climate-Anxiety Future

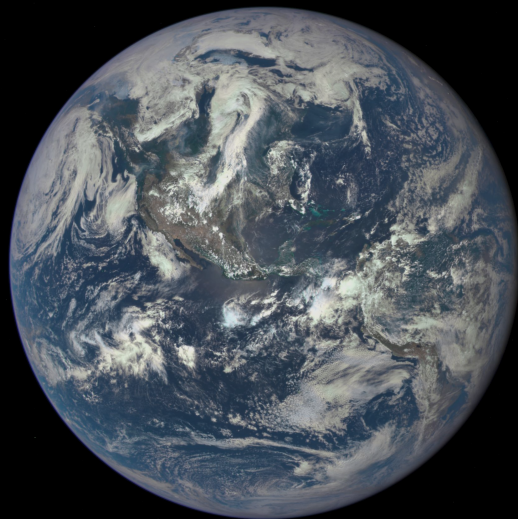


Humanity has moved on to exciting new things because
climate is under control

Google Research

Image: Surface of Mars, NASA/JPL

What do we need on a planetary scale?



"Listen to what the scientists say"

-- Greta Thunberg

Source: [TheGuardian.com](https://www.theguardian.com)

Image: NASA

Geo-Engineering

"If people trusted climate change models we'd be putting aerosols into the air today."

-- climate scientist *Ken Caldeira*

Carbon Sequestration

"Bio-sequestration is for real, and people have ignored it... This is a technology the world needs. It is part of the climate change problem that no one else has really addressed."

-- biologist and geneticist *Joanne Chory*

Energy Growth and Transformations

"Nuclear power paves the only viable path forward on climate change."

-- climate scientists *James Hansen, Kerry Emanuel, Ken Caldeira and Tom Wigley*

Futuristic Geo-Engineering

Why

Weather affects water, crops, life and property. We're decades away from turning down the trend in CO₂ emissions.



Proof point

Nature: In the past, volcanic dust clouds lowered global temperatures; Humans: Cloud-seeding has been done for decades.



Within Reach

Chemical means: Cloud brightening & seeding; then Biological means

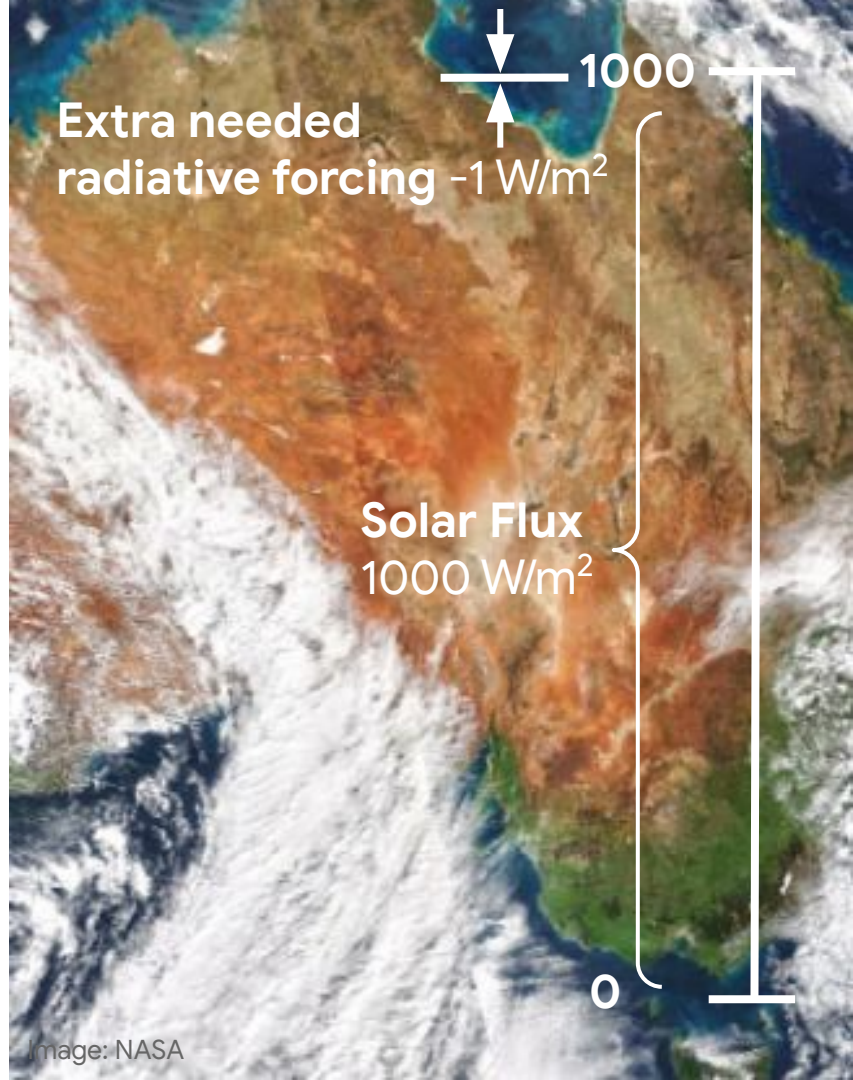


Image: NASA

Futuristic Carbon Sequestration

Why

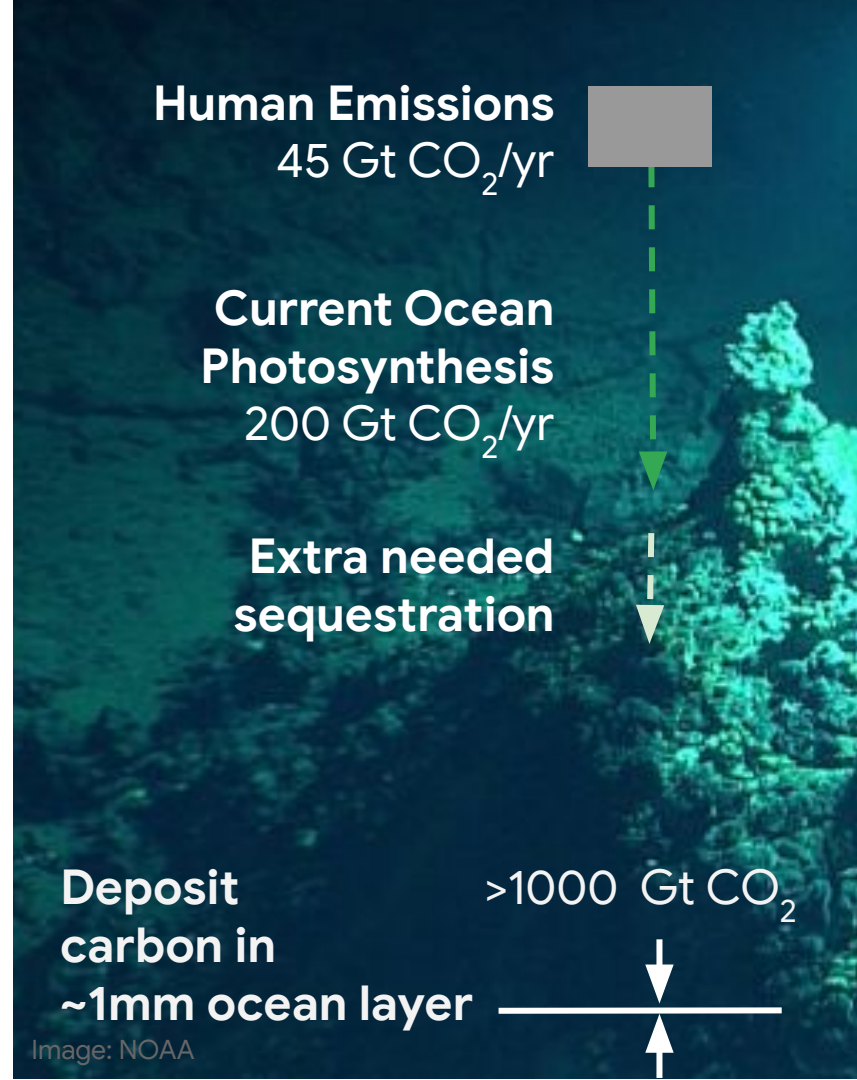
Reduce atmospheric PPM CO₂. Sequester > 1000 Gt CO₂ at a rate in excess of 20 GtCO₂/yr to restore weather and keep oceans from rising long term.

✓ Proof point

Carboniferous era: lignin pulled CO₂ from ~900 ppm down to 300 ppm. It took nature millions of years to evolve a way to digest lignin.

✓ Within Reach

Biotechnology offers more tools for enhancing ocean carbon sequestration.



Futuristic Energy

Why

More / cheaper / better non-fossil fuels & electricity



Proof Point

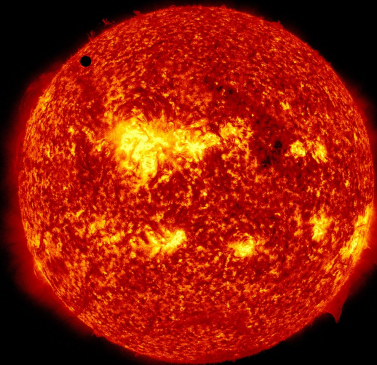
There is no shortage of energy, only ways to economically access it. Using 1960's technology, France, Sweden, Ontario essentially decarbonized their electricity in a decade.



Within Reach

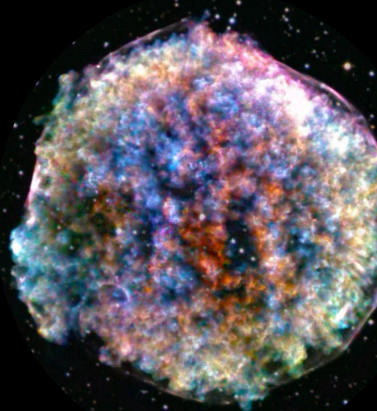
New materials and processes, but real progress needs to be made to enable futuristic energy

Stars



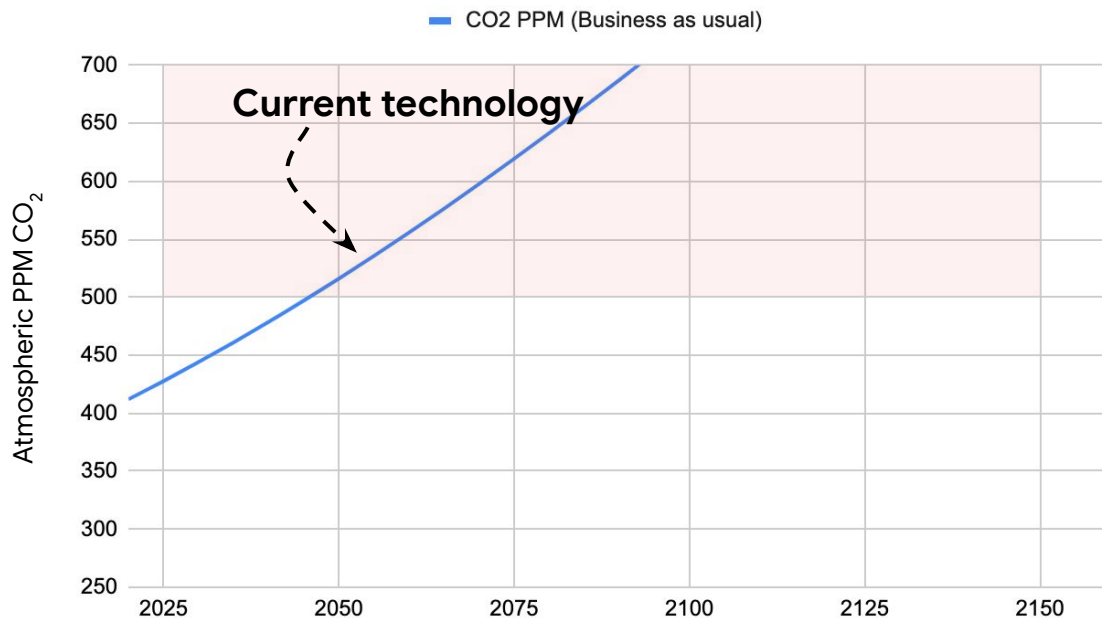
Fusion
Photosynthesis
Hydro
Solar PV
Wind
Fossil Fuels

Supernovae



Fission
Geothermal

A scenario where climate is out of control



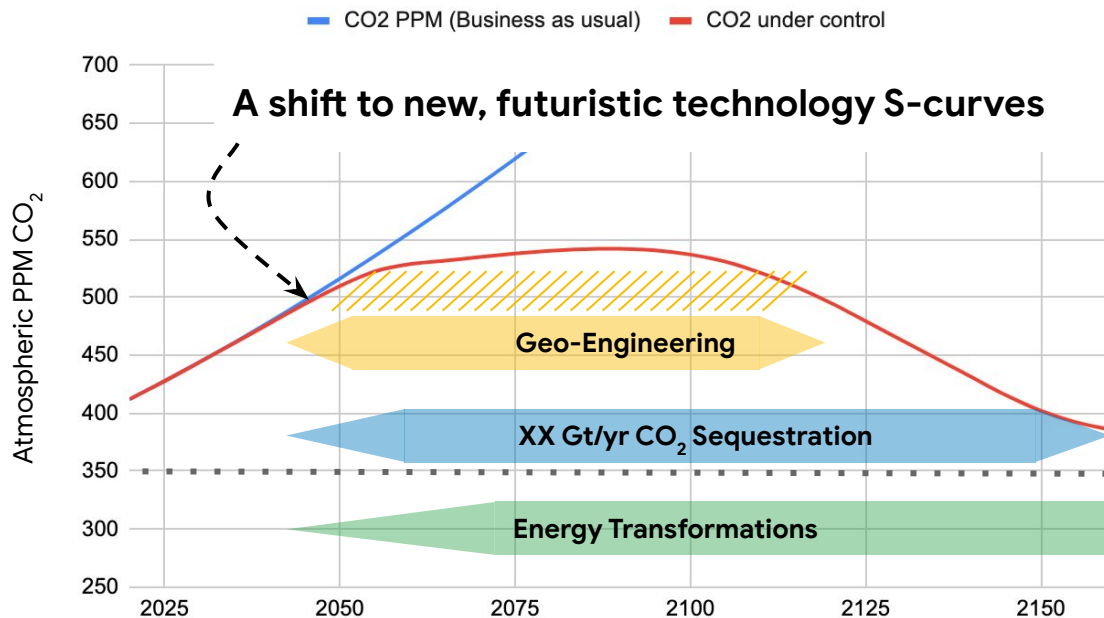
Business as Usual: CO₂ goes up

“The definition of insanity is doing the same thing over and over again, **but expecting different results.**”

-- Albert Einstein

What makes the future different is that some things are **futuristic.**

A scenario where climate is under control



Synthetic biology does the heavy work, driving down CO₂ by sequestering > 1000 Gt.

Zero-CO₂ energy transformations in stationary and mobile use cases at global scale reduce CO₂ emissions from 40Gt/yr to near zero.

We've made
planetary-scale
impacts within a
lifetime

We will do so again
and again

What's holding us
back on climate?

Polio

Dengue

Measles

Flu



Unlocking futuristic breakthroughs

Have the **best people** working on the **most important problems** in an environment where **discovery, innovation and deployment thrive.**

Unlocking **futuristic** breakthroughs

Play to Win

New Tools

**Creative
Funding**

**Supportive
Environment**

Play to win

“Why should we invest in research instead of deploying <technology>?”

This is [playing not to lose](#) one battle

.. but the goal should be to *maximize the chances of winning the war* on climate change.



Play to win

“Why should we invest in research instead of deploying <technology>?”

This is playing not to lose one battle

.. but the goal should be to *maximize the chances of winning the war* on climate change.

“Playing to Win” maximizes the chances of winning the war on climate change

- Taking risks is essential.
- Playing many games increases the odds of success



Keep placing bets on tough problems in weather, sequestration, and energy. This gets us to a climate change solution as quickly as possible.

The riskiest thing to do is not place these bets.

Play to win



“Playing to Win” maximizes the chances of winning the war on climate change

- Taking risks is essential.
- Playing many games increases the odds of success
- Cuttlefish have passed the marshmallow test



Keep placing bets on tough problems in weather, sequestration, and energy. This gets us to a climate change solution as quickly as possible.

The riskiest thing to do is not place these bets.

Create a supportive environment

“Why should we put faith in technology that we don’t already have?”

Fear, ideology, and the status quo hinders creativity and innovation.



Image: Caproni's crash, public domain

“If you don’t fail, you’re not even trying.” **Every failed experiment is one step closer to success.**

-- Denzel Washington

Source: [Commencement Speech](#), t=13:10

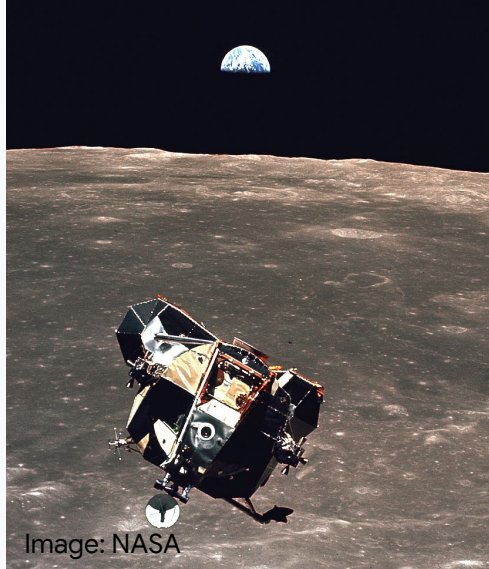
Create a supportive environment

“Why should we put faith in technology that we don’t already have?”

Fear, ideology, and the status quo hinders creativity and innovation

Ensure psychological safety

- For researchers, to try, to fail
- For today’s early funders



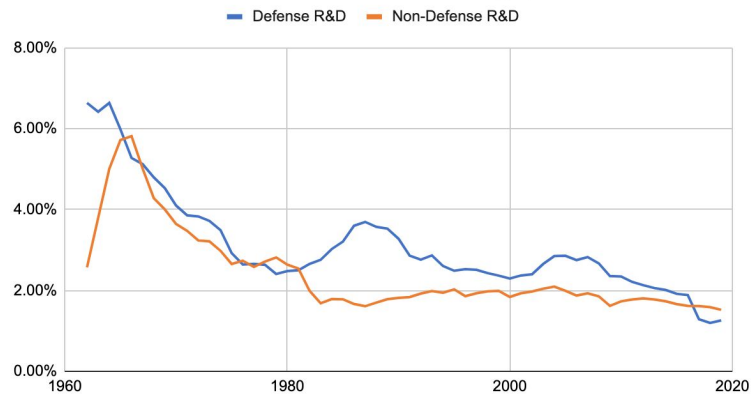
“The key question to keep asking is, Are you spending your time on the right things? Because time is all you have.”

-- Randy Pausch

Source: [The Last Lecture](#)

End of historic funding

Federal R&D as a Share of the Total Budget, 1962 - 2020



Data Source: AAAS

Bell Labs



NASA



Google Research

Get creative with funding

Vibrant communities are emerging in geo-engineering, carbon sequestration, and advanced energy

Donors & philanthropic organizations have the resources to jump-start science

Things to address:

- Connect science to achieving goals
- Program management
 - Tailored research proposals
 - Due diligence
 - PhD cycle funding



The logo for the Bill & Melinda Gates Foundation, which is a black rectangular box containing the text "BILL & MELINDA GATES foundation" in white. "GATES" is in a larger, bold serif font, while "foundation" is in a smaller, lowercase serif font.



etc. etc.



Build new tools

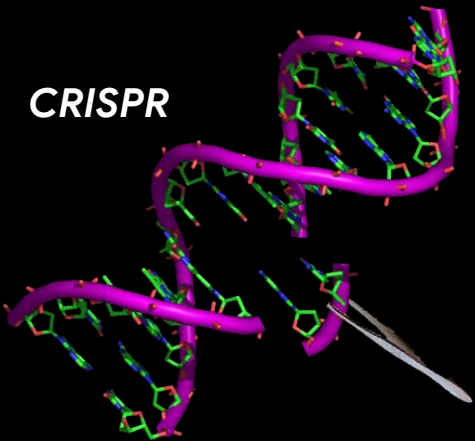
Today

CRISPR, Multidimensional experimentation, and Machine Learning

Soon

Quantum Computing can transform Chemistry / Biology / Physics / Material Science, etc

CRISPR



**Machine
Learning**



**Quantum
Computing**

Build new tools

Today

CRISPR, Multidimensional experimentation, and Machine Learning

Are key problems / experiments posed?

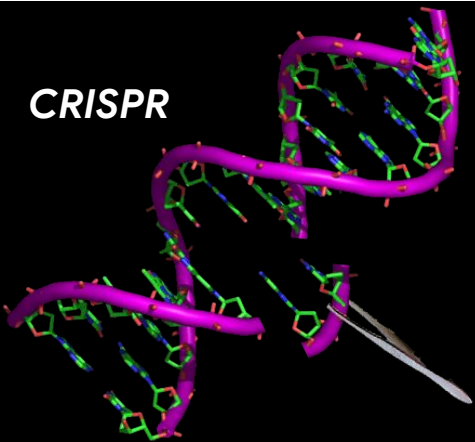
- Geo-engineering - materials (albedo reduction)
- Carbon sequestration - genomics / proteins (ocean biotech)
- Transformative energy - atomic / nucleonic models

If not, why not?

Soon

Quantum Computing can transform Chemistry / Biology / Physics / Material Science, etc

CRISPR



Machine Learning



Quantum Computing

Quantum Computing as a new tool

QC can tackle some seemingly impossible problems - Not just a faster computer: requires cross-disciplinary expertise

- Would this unlock amazing capabilities for your work? Reach out to someone proficient in QC
- Do you aspire to changing the world with QC? Learn it; connect with scientists
- Start with something simple, iterate, craft breakthrough proposals



Colab
Platform allowing anyone to run python code via their browser



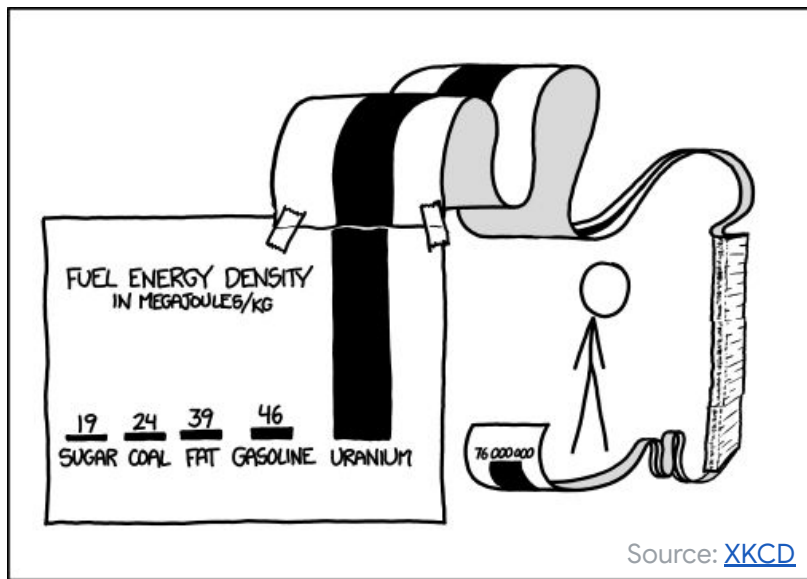
Circ
Open source for creating quantum circuits and running on quantum computers and simulators.



OpenFermion
Open source for simulating fermionic systems inc. quantum chemistry and materials science



Deeper dive into futuristic energy



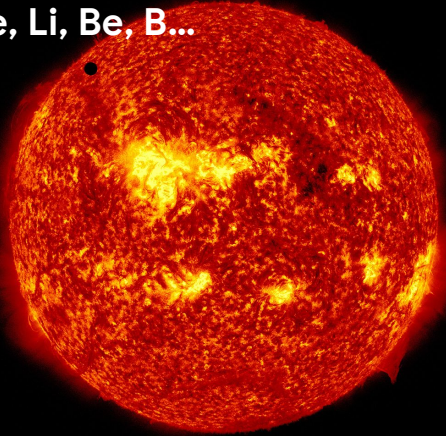
Unlocking energy at mind-boggling scale

SCIENCE TIP: LOG SCALES ARE FOR QUITTERS WHO CAN'T FIND ENOUGH PAPER TO MAKE THEIR POINT PROPERLY.

$$E = mc^2$$

Small Nuclei

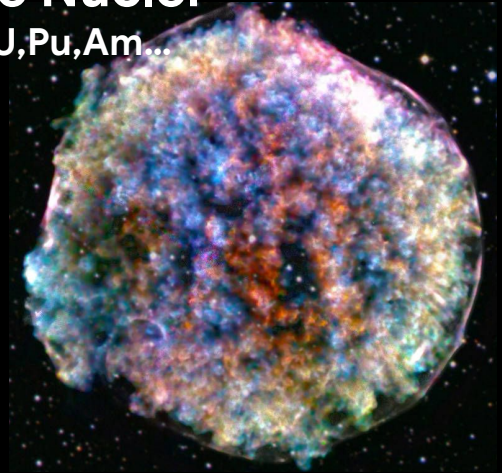
H, He, Li, Be, B...



Solar fusion @ 2 mW/kg

Large Nuclei

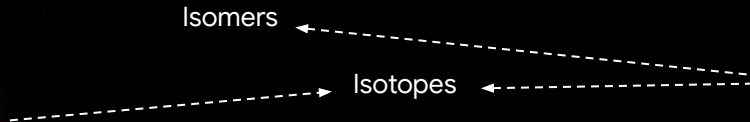
Th, Pa, U, Pu, Am...



Pressurized H₂O reactor fission @ 1 kW/kg

Isomers

Isotopes



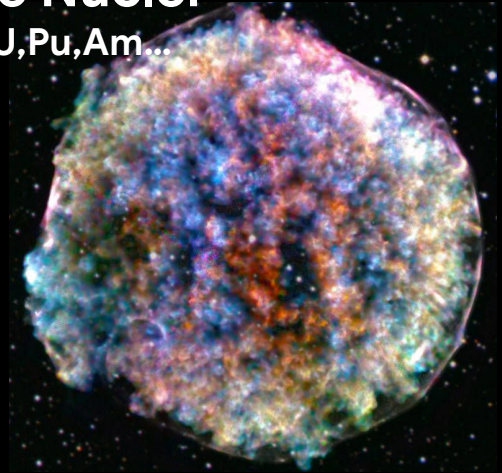
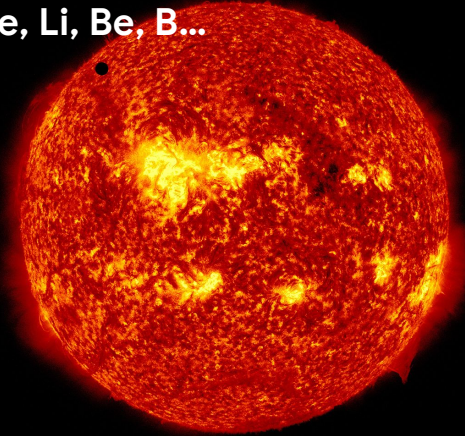
$$E = mc^2$$

Small Nuclei

H, He, Li, Be, B...

Large Nuclei

Th, Pa, U, Pu, Am...



Isomers

Isotopes

**Knowledge, Capability,
Precision, and Control**

Solar fusion @ 2 mW/kg

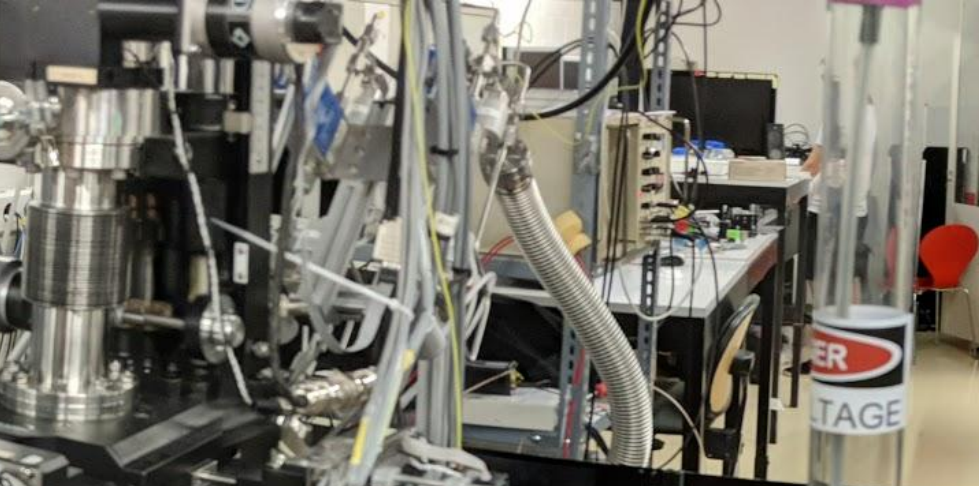
Pressurized H₂O reactor fission @ 1 kW/kg

Need: New technology for stable, high-energy plasmas, power conversion, low cost

Need: New technology for lower cost, waste elimination, even better safety

**Mass Manufacturing,
Lower Cost**

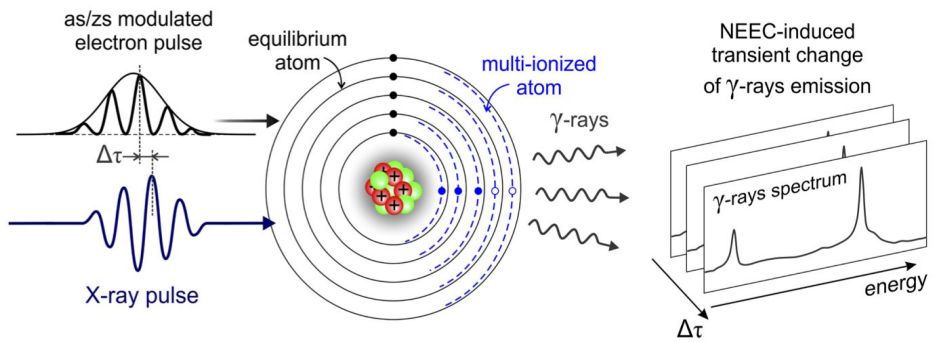
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Precise atomic power in a portable form

Can we get exactly and only the reactions we want
in a portable power pack?





Precise atomic power in a portable form

Can we get exactly and only the reactions we want in a portable power pack? *Maybe.*

Nuclear Excitation by Electron Capture (NEEC)

- Select nucleus & transition and influence path through Timing, Energy, Orbital angular momentum
- No nuclear chain reactions
- Small apparatus: laser, electron accelerator
- Applications to energy and nuclear waste destruction

DAQS?



Nuclear Engineering

Google Research

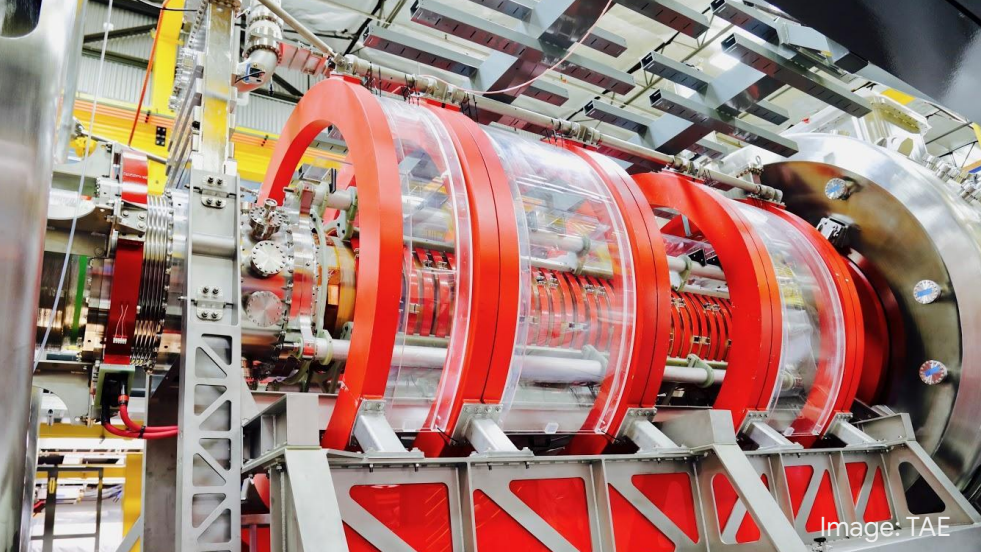


Image: TAE

Fusion Technology

Cross-pollinate expertise from different fields: Google's Machine Learning and Plasma Physics

Application of machine-learning to to improve TAE's plasma performance for nuclear fusion

SCIENTIFIC REPORTS

OPEN Achievement of Sustained Net Plasma Heating in a Fusion Experiment with the Optometrist Algorithm



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S.512 - Nuclear Energy Innovation and Modernization Act

115th Congress (2017-2018)

LAW Hide Overview ✕

Sponsor: [Sen. Barrasso, John \[R-WY\]](#) (Introduced 03/02/2017)

Committees: Senate - Environment and Public Works

Committee Reports: [S. Rept. 115-86](#); [S. Rept. 115-86](#)

Latest Action: 01/14/2019 Became Public Law No: 115-439. ([All Actions](#))

S.97 - Nuclear Energy Innovation Capabilities Act of 2017

115th Congress (2017-2018)

LAW Hide Overview ✕

Sponsor: [Sen. Crapo, Mike \[R-ID\]](#) (Introduced 01/11/2017)

Committees: Senate - Energy and Natural Resources

Committee Reports: [S. Rept. 115-115](#)

Latest Action: 09/28/2018 Became Public Law No: 115-248. ([All Actions](#))

H.R.589 - Department of Energy Research and Innovation Act

115th Congress (2017-2018)

LAW Hide Overview ✕

Sponsor: Rep. Smith, Lamar [R-TX-21] (Introduced 01/20/2017)

Committees: House - Science, Space, and Technology | Senate - Energy and Natural Resources

Committee Reports: [S. Rept. 115-242](#)

Latest Action: 09/28/2018 Became Public Law No: 115-246. ([All Actions](#))

Tracker:

Introduced > Passed House > Passed Senate > Resolving Differences > To President > **Became Law**

Advanced Energy Policy

Drive productive dialog and policy

Increase momentum in advanced energy research, development, and innovation



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Existing Technology

Futuristic, Transformative energy in 3 phases

Advanced Fission Technology

- Recycling spent fuel & bomb material
- Transmuting nuclear waste
- Carbon-neutral Hydrogen, Fuel / Ammonia

In large nations on Earth, decarbonize electric sector and industries

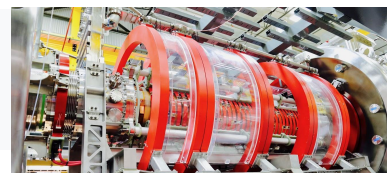


Oklo

Fusion Technology

- Universal carbon-free electricity
- Interplanetary space transport

On Earth, decarbonize electric sector in advanced economies

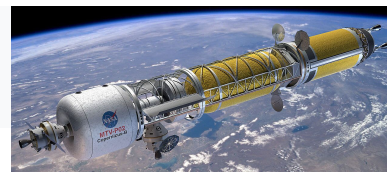


TAE

Portable Power Technology

Planes, vehicles, ships, homes, portable devices

On Earth, decarbonize remaining oil & gas

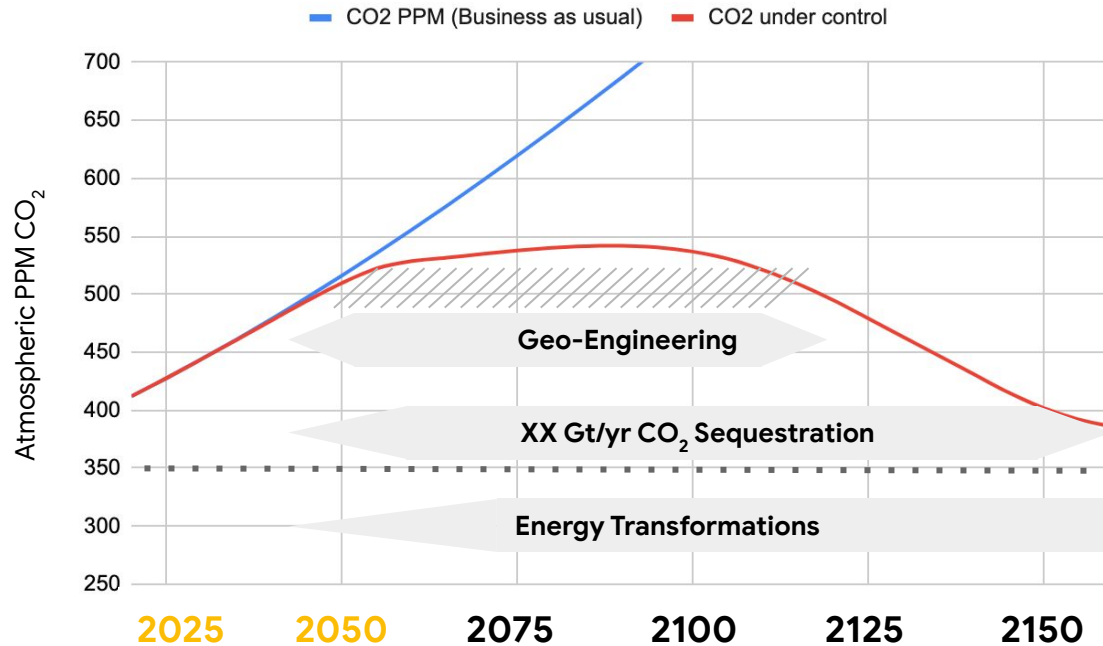


NASA

100% Deep Decarbonization

These also
make Mars
increasingly
viable

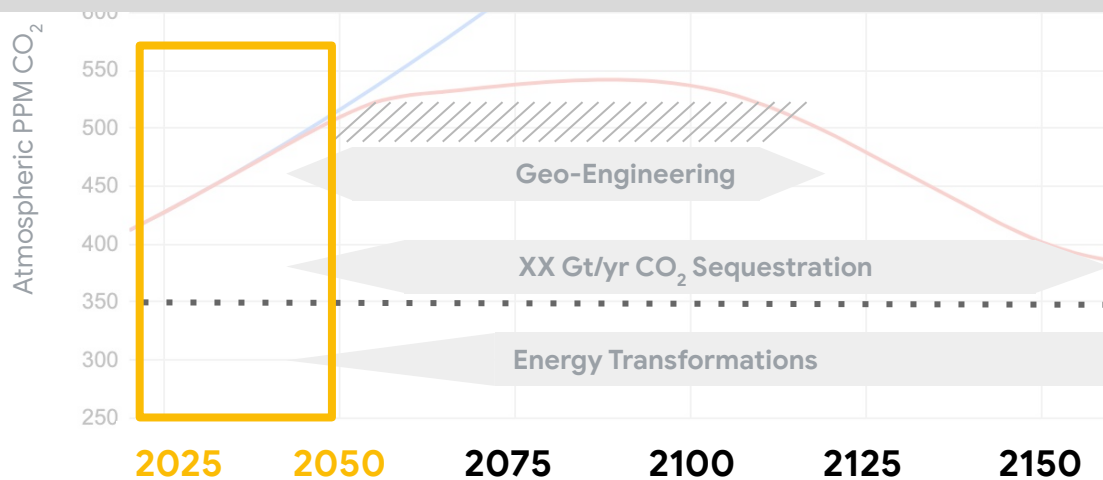
... and timeline to solve climate change




... and timeline to solve climate change

Do you have pieces of the solution?

In the back of your mind; in an old grant proposal,
from a weekend conversation, ...





Can your research lead to futuristic
planetary-scale climate impact?

Can it be unblocked by quantum computing?

Tell us. Let's make the future awesome!

Ross Koningstein

Google Research | Climate and Energy

[Ross \(at\) google.com](mailto:rosskoningstein@google.com)

[@rosskoningstein](https://twitter.com/rosskoningstein)

Google Research

Image: Surface of Mars, NASA/JPL

Thank you

Ross Koningstein

Google Research | Climate and Energy

ross@google.com

[@rosskoningstein](https://twitter.com/rosskoningstein)

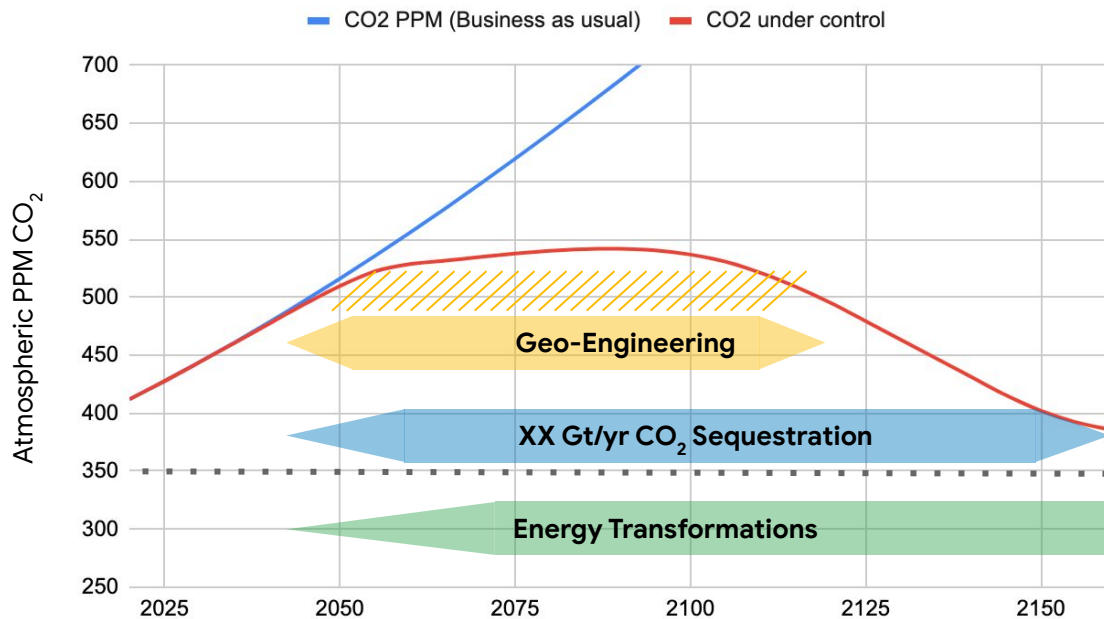
Follow-up reading material:

- Climate change and human civilization <https://xkcd.com/1732/>
- Three essential parts of climate change solution [The four environmental heresies TED talk by Stewart Brand](#)
 - The U.S. Energy Information Administration's latest [International Energy Outlook 2017](#) (IEO2017) projects that world energy consumption will grow by 28% between 2015 and 2040
 - Radiative forcing to compensate for elevated CO₂ and other gasses is on the order of 1 W/m²; 1/10 of a percent of solar irradiation
 - Enhanced biological ocean carbon sequestration. Reading: [Middelburg 2019](#) [Article by Antonius Gagern](#)
 - sequestration rate target should exceed where emissions will be at peak CO₂. Today that is 40Gt/yr CO₂. <https://www.co2.earth/global-co2-emissions>
 - Ocean primary productivity uses 200Gt CO₂/yr ([wikipedia](#)). Note productivity usually measured in C, while atmospheric emissions are measured in CO₂.
 - A target quantity of >1000 Gt CO₂ figure to pull out of the atmosphere per IPCC, current total emissions debt ~ 2000 Gt CO₂.
 - A biotechnology-enhanced approach, using minimal physical infrastructure, may offer the lowest \$/ton CO₂ sequestration. A mechanical approach to pull CO₂ out of the atmosphere, and particularly to put into some recalcitrant form, could require a similar amount of energy as gained from fossil fuels used over the last 200 years.
 - Electricity system transitions are possible in a decade: Energy Transformation: Industrial time cycle, industrial delta so change will not happen right away. [Sweden's buildout](#), [Ontario's buildout](#), [France's buildout](#)
- We need new technology to get on a different trajectory for climate change. See this [paper](#) in IEEE spectrum.
- Climate Solution metric: the probability of solving climate change, maximize this given resources and new inventions
- Funding for fundamental science: [The Future Postponed](#)
- Efforts in possibilities for future atomic energy
 - NEEC at [EPFL](#), and [UC Berkeley](#)
 - Fusion: Scientific Reports: [Achievement of Sustained Net Plasma Heating in a Fusion Experiment with the Optometrist Algorithm](#),
 - Policy to support innovation: [Advanced nuclear energy policy campaign](#)

Agenda

- 01 A Post-Climate-Anxiety Future
- 02 What do we need on a planetary scale?
- 03 Unlocking futuristic breakthroughs
- 04 Quantum computing as a new tool
- 05 Deep dive into futuristic energy
- 06 Let's make the future awesome

A scenario where climate is under control



Synthetic biology does the heavy work, driving down CO₂ by sequestering > 1000 Gt.

Zero-CO₂ energy transformations in stationary and mobile use cases at global scale reduce CO₂ emissions from 40Gt/yr to near zero.

End of historic funding

Bell Labs and the NASA moon landings are in the past.

Today, there is less funding for discovery-oriented science which results in fewer advancements.

Reading: [The Future Postponed](#)

Bell Labs



NASA



Google Research Presentation Template: Guidelines



- This template is for both internal and external slide presentations, and presents several options for 1) Title Slides 2) Agenda Slides 3) Transition Slides 4) Content Slides and 5) Conclusions/Acknowledgements. It is aimed at ensuring a consistent and recognizable “Google Research” brand. Please make a copy of this deck, and feel free to choose the slide options that you prefer.
- On the title slide, please follow guidelines for affiliation found at go/research-branding.
- Refrain from using any externally approved team/product logos on any slide except the Conclusion/Acknowledgements slide at the end of your presentation. Of course, if the talk is about a product (e.g. TF, or Chrome, etc), there likely will be instances where you use that branding on slides other than conclusions. But we do ask to not use (externally approved!) team logos till the end.
- Minor modifications to slides is ok, assuming the above guidelines are met