The rise and fall of lithium:
+60 million tons of opportunity

2017-01-25

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The views, estimates, and opinions expressed in this presentation are those of the author and do not necessarily reflect the position of Lithium Americas Corp.

I would like to thank Cormark for the opportunity to speak with you today. It is a pleasure and an honor to be invited to deliver today's keynote speech, especially in Toronto, where I was born and did my undergraduate degree.

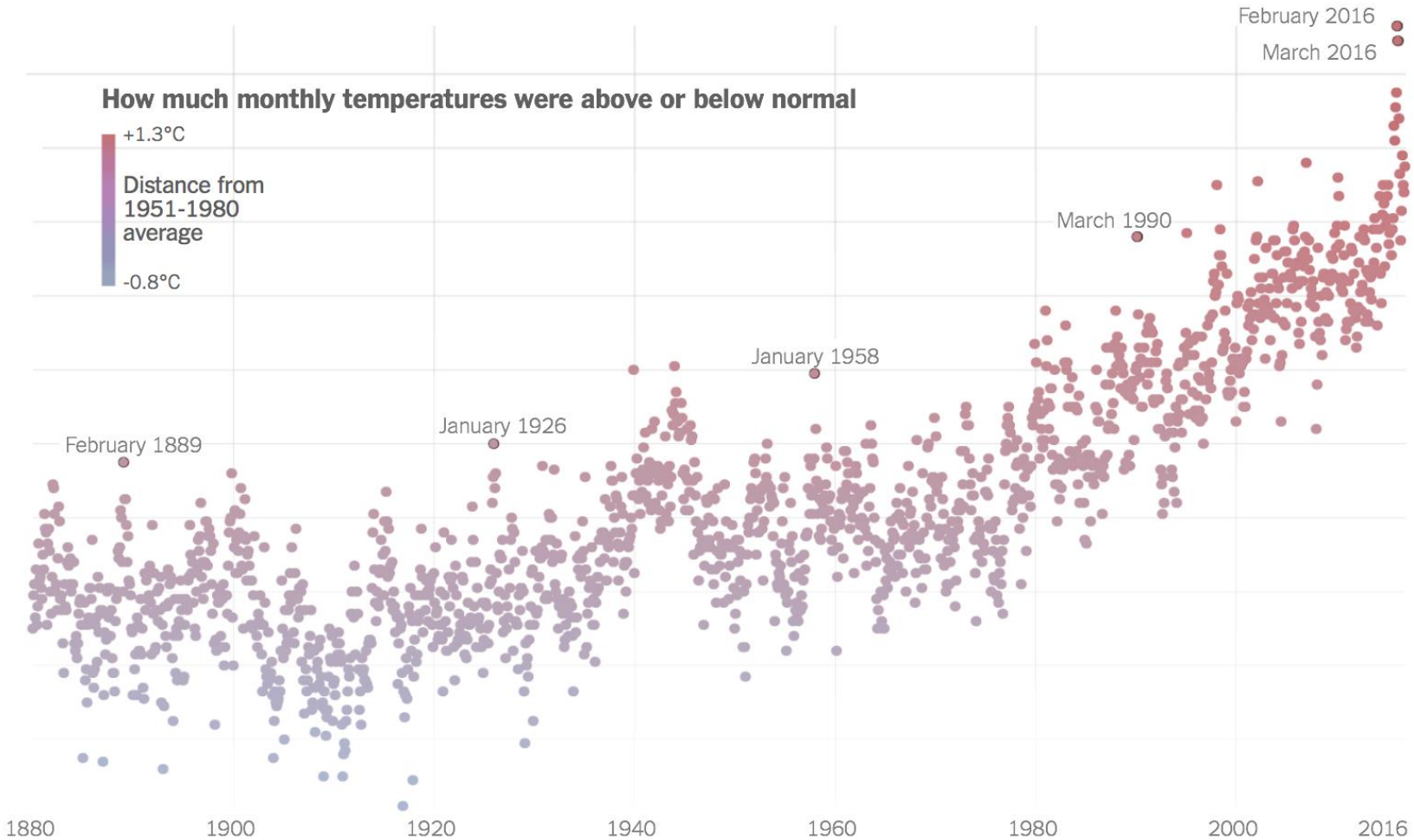
Why are we here, in this venue together? You may think it is to discuss lithium or batteries technology opportunities. This is partially true. Why are we really here? We are here to address a much bigger issue, tied to the energy revolution and the desires of traveling consumers, where lithium, and batteries technologies opportunities offer critical solutions to these issues.

Here is where I went hiking last month in Chile with my wife and baby daughter. It's a beautiful part of the world. Up in the corner you'll see snow. If you look closely enough, it is possible to make out a glacier. While out there, at 2000 m altitude, I made the comment to my wife: "If our daughter comes back here when she's an adult, or if we come back here with grandchildren, that glacier may no longer be there for us to see."

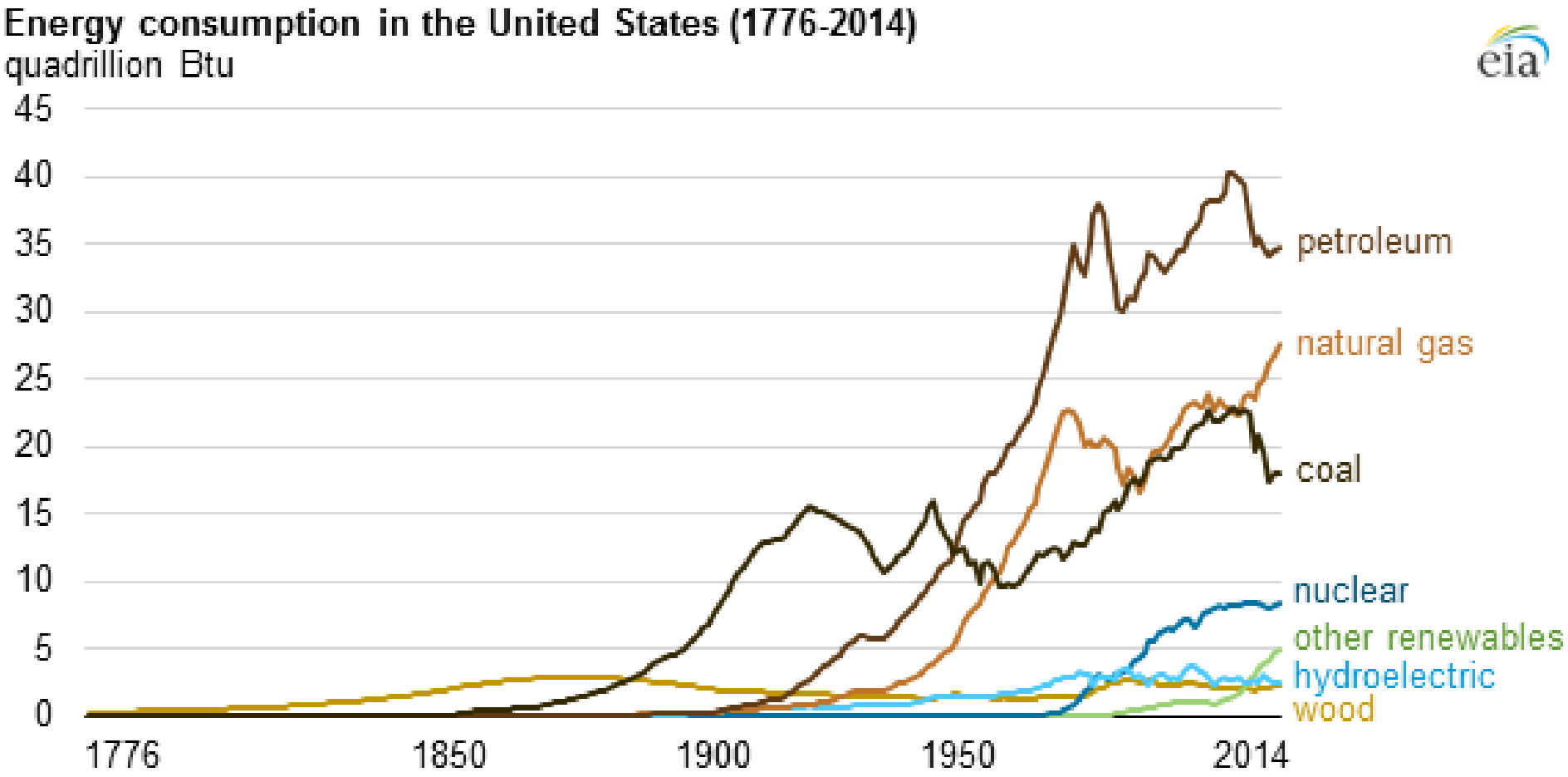
To provide some hard data on this observation. When Glacier National Park was established in 1910, there were 150 glaciers. Now there are 25. By 2030 there are expected to be zero. At another climate extreme, the Atacama Desert has not seen rain in over 800 years, until 2 years ago. This rain, by the way, did affect lithium operations in the area.

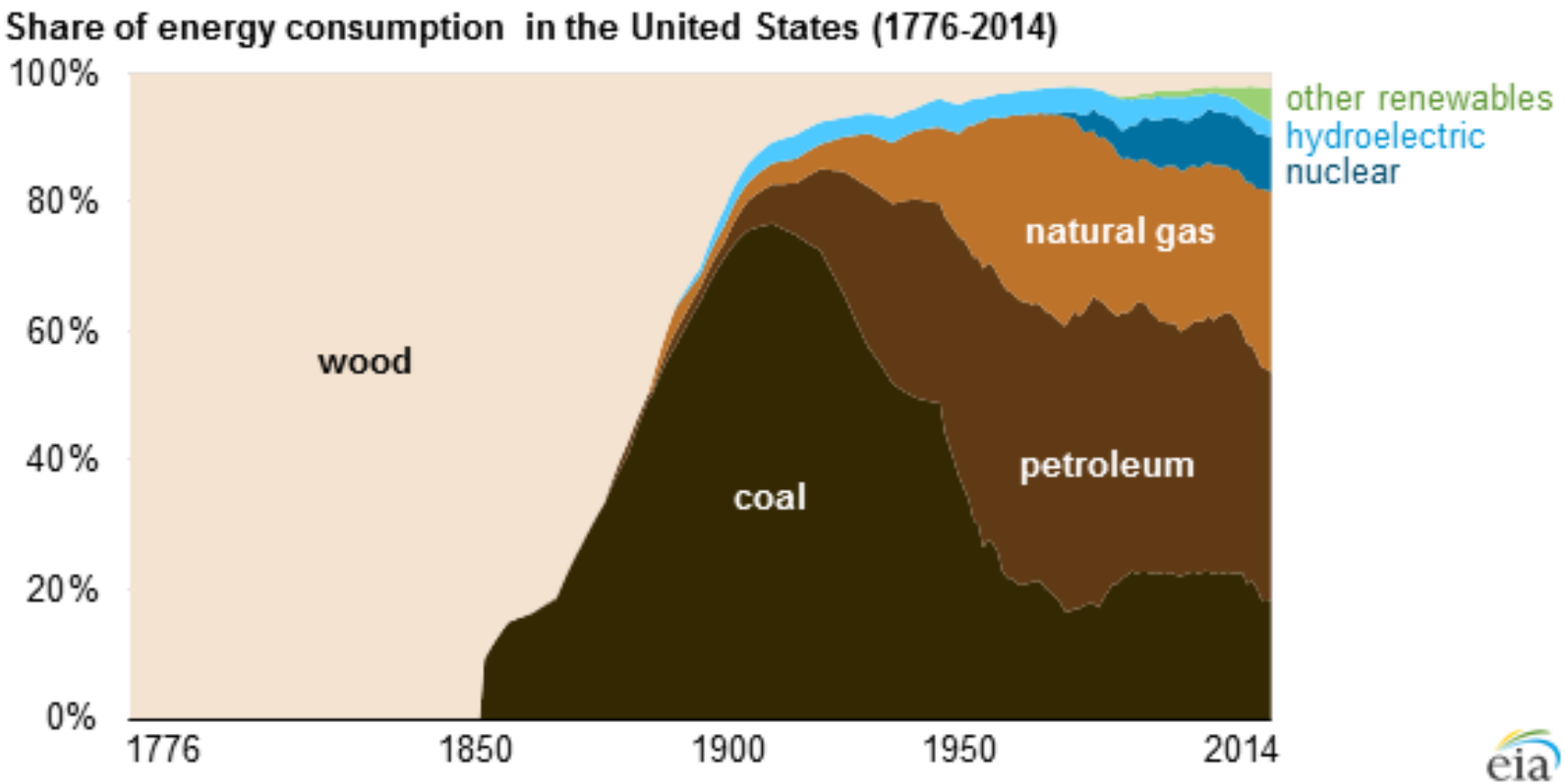
Worldwide, we are seeing such changes happening before our very eyes; and these changes are accelerating. Climate change is happening. The cause of it, raising levels of GHGs, is obvious and clear.

This graph was pulled from a New York Times article last week, and compiled from data from different agencies and scientific outfits across the world. The picture speaks for itself. The consequences, of course, are difficult to predict and simulate locally, but not impossible.



Yet, global prosperity and growth has been fueled on a carbon-intensive base-load. Much of our progress in the industrial and post-industrial age is thanks to the abundance of and easy access to fossil fuels. The growth on these graphs closely align with prosperity. Moving forward, however, it may not be such a smart idea to rely on the assumption that fuel is cheap, abundant and readily accessible.



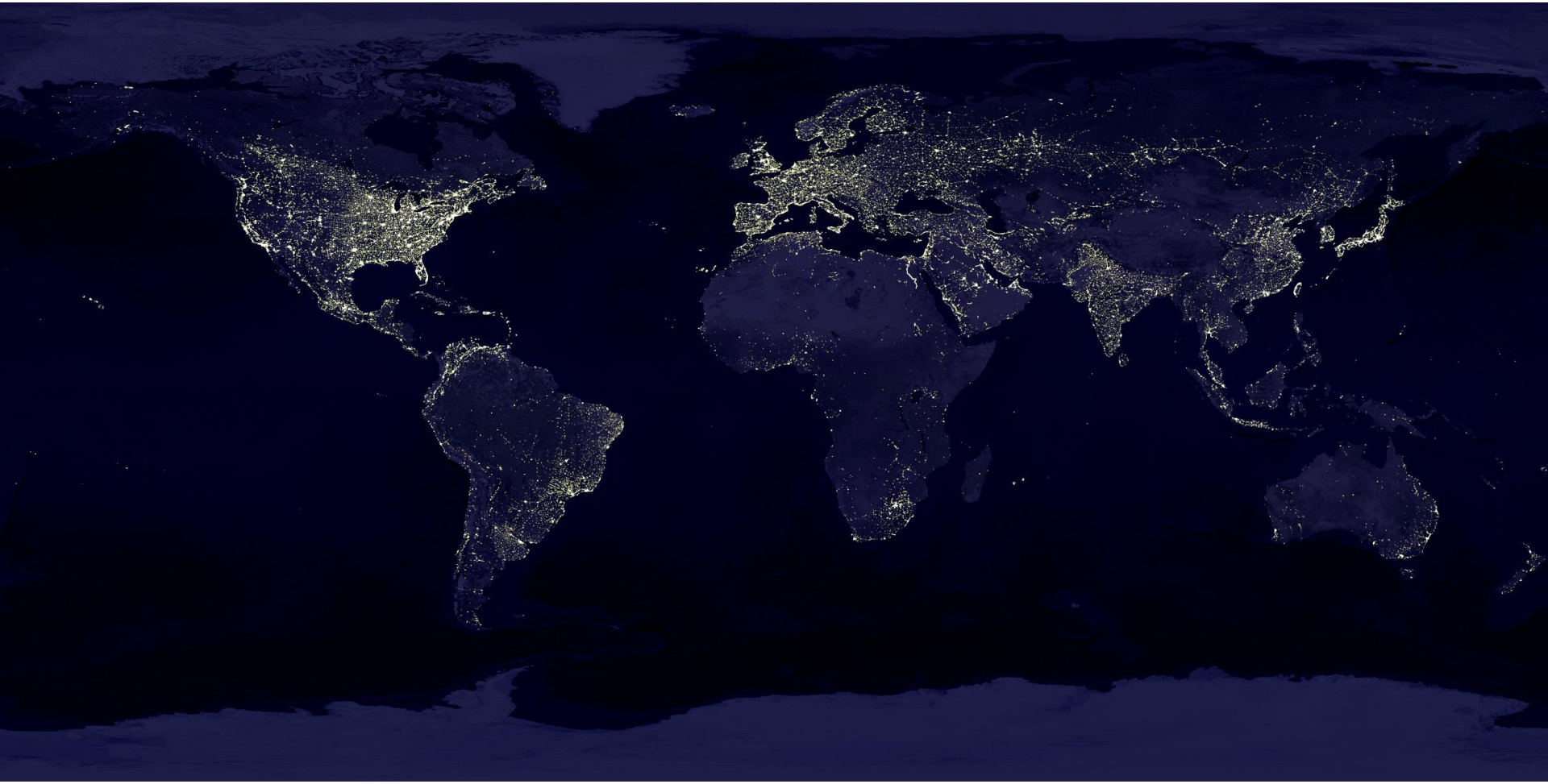

Share of energy consumption in the United States (1776-2014)
100%
80%
60%
40%
20%
0%
1776
1850
1900
1950
2014
wood
coal
petroleum
natural gas
other renewables
hydroelectric
nuclear
eia

We need to figure out how to keep the lights on. Or indeed, enable parts of the world that are in energy poverty, to turn the lights on. I think there is a way to do it, without the need for carbon-intense sources and technology. Many solutions already exist, and are economical today. We can turn lights on, and transport ourselves around, without the need for fossil fuels. And we do not need to compromise on comfort, convenience, nor cost.

Take for example, what's going on in Europe. In Norway, there were several months over the last year or two where Tesla's EV where the most popular car to buy. Over 40% of Denmark power comes from renewables, and that percentage is growing; Danes are consistently ranked as the happiest and prosperous people in the world. As of this year, all trains in the Netherlands are now powered by wind.

The key to transitioning out of a carbon economy globally? Two changes are needed. Electrifying transportation; and figuring out a cheap solution to energy storage.

Today, electricity is generated moments before we use it. It's the largest supply chain in the world, with no warehouse. We need to fix that. Conversely, we currently run a complex O&G supply chain that enables us to transport ourselves and goods on combustible fuels. This supply chain creates enough pollution to kill 7MM people a year. Think about that. Is this acceptable?



Our way forward, as we already move toward renewables and EV, will largely depend on our ability to deliver lithium to the world. Lithium is central to any mobile energy storage technology. We have what's available to us on the periodic table. It's impossible to avoid the lightness and electrochemical potential that lithium brings to the table, literally and figuratively. It also happens to be relatively abundant. Yes, there is enough lithium in the ground to electrify every car in the world, plus some. And we will need to figure out how to mine this wonderful material in the most sustainable, environmentally restorative ways imaginable. So let's focus on how this is going to happen.

But first, I want to convince you that electric vehicles are a pretty safe bet for the auto industry's next wave of growth – regardless of climate change issues and government policies.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
**	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

How many of you have driven in an electric car?
How many of you own an electric car?
How many of you have driven in a Tesla?
Or, better, have had a Tesla drive you, or watch it park itself?

For those who have not experienced driving in an electric car, you're missing out. The experience is extraordinary. Think of a car that accelerates faster and more smoothly than a Ferrari, with barely a whisper as you are thrusted forward. Think of that same car accommodating for an entire family.

Think of the time you commute to work in a car, and how you can get that time back, safely, when your car ends up driving itself. Oh, and by the way, with such a car, you'll never have to pay for petrol again. Imagine it.

I am not here to sell Tesla's. Tesla's sell themselves. What I do want to impress upon you, however, is that we've reached a point of no return. There is no turning back on old technology. No OEM can be serious about competing against the superior user experience of driving an EV, with autonomous features and all. It's like trading in your iPhone for an old Nokia – you just cannot do it. In 3 to 5 years from now, when consumers are faced with the choice between a $30k Honda Accord or Toyota Prius, or a Tesla Model 3 or let's say an Audi E4, the choice will be pretty clear.

So, let's move forward on the thesis. That within just a few years, consumer demand will push smart OEM's, and some new-comers into the EV race. OEM's will revamp their supply chain accordingly. Some are doing so now, particularly in Asia.

What will happen to the supply chain of raw materials? Most materials that go into vehicles and the batteries that power EVs are commoditized. Steel, glass, rubber, aluminum, plastics. These industries are large and cyclical. There is one glaring exception: lithium.

Right now, lithium is characterized as a specialty chemical. Last year, sales reached over $1B, with 35 to 45% of the market going to Li batteries. The lithium market is tiny compared to say, nickel or copper. Let's take a closer look at the market numbers and provide some context. In 2016, around 170 to 180kt LCE of lithium was produced and consumed. That is around 3 to 4 Gigafactories worth of lithium. If all of it went to making batteries for EV's that would be around 3 to 4 million EV's worth of lithium.

Now, for clarity, I am defining a Gigafactory to be a battery factor that produces around 100 GWh's of electricity per year.

Where is the industry going in the years ahead? We can do an entire exercise right now to try and size, then predict in detail, the demand for lithium. But I am not going to do that. Instead, let's consider the fact that most Western OEM's have announced in one form or another, serious EV programs. Then there is everything that is going on in China, with its centralized approach to moving mountains. Now, let's focus on just two OEM example EV programs: Tesla and VW.

After the unveiling of Tesla's Model 3, almost 400,000 pre-orders came in last April, requiring a $1000 refundable deposit by customers. That's unprecedented. iPhone sales have never performed that well. Soon after, the CEO of Tesla, Elon Musk decided to double the production goals of its Gigafactory and vehicle plant in Fremont. So, the Gigafactory will produce enough batteries to produce 1m EV's per year, plus some for Tesla's Energy business. That's around 100 GWh's or more of battery production per year, by around 2020 or soon after.

Meanwhile, VW made bold announcements, with a guidance that 2 to 3m EV's will be in production by the early 2020's. Now, we can argue about how fast or slow the ramps will be, and how quickly such OEM's can come to market. But let's stay focused on these two examples, Tesla and VW. Within about 5 years, these two OEM's will be on target to produce 3-4 m EV's, with 3-4 supporting Gigafactories worth of battery production. The lithium required for this kind of market is double what is produced by the lithium market today.

Again, the demand from Tesla and VW alone will require doubling the market size of lithium in 5 years. I have not accounted for the demands of Ford, Daimler, Volvo, BMW, Faraday Future, Lucid, Apple, or the colossal demands of China. Indeed, the battery factories that feed OEM EV production need to be built. As of now, I am aware of Gigafactory plans in the USA, Germany, Sweden, Poland, Hungary, and throughout Asia. Much needs to happen, starting with the necessary investments.

Lithium Industry 2016	Order of magnitude
Sales	Over $1B
Volume	160k to 180k tpa LCE
# of Gigafactory equivalents	3 to 4

*** What's a Gigafactory? A battery factory that can produce enough Li-ion batteries to produce about 1m EV's per year. Original term coined by Tesla.**

What does this mean for the Li industry?

1. Unprecedented growth

2. Rapid technological change

	# of EVs	t LCE
Gigafactory (per year)	1,000,000	50,000
Gigafactory (total over 20 yr)	20,000,000	1,000,000
USA	250,000,000	12,500,000
World	1,250,000,000	62,500,000

*** Almost 100 Gigafactories, operating for 20 years each, are needed to electrify the world's fleet of vehicles, and enable segments of the energy storage market.**

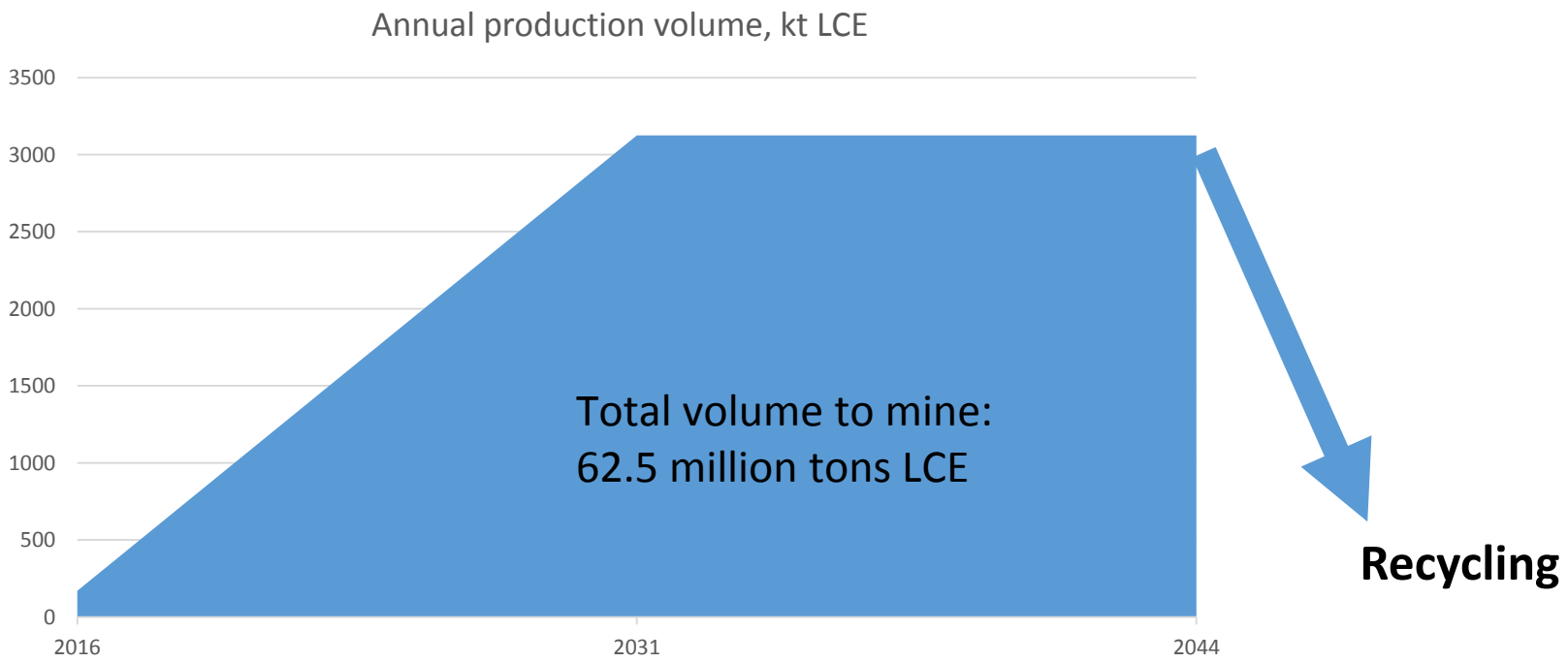
SCALE

Let's focus on the growth aspect. We need to think big. The industry can no longer think in terms of incremental growth. We need to think in terms of Gigafactory quantities. Not in thousands of tons LCE, but 50ktpa growth quanta. One Gigafactory will enable the production of 1m EVs' per year, or 20m EVs over the factory's lifetime.

This means we need 12 or 13 Gigafactories to electrify every car in the USA, or around 65 Gigafactories to electrify the world. Each Gigafactory needs 50ktpa LCE of lithium for 20 years. A total of over 62.5m t LCE needs to be mined to electrify the world's fleet of vehicles. That's it. Only 60m odd t LCE.

To electrify the world's fleet of vehicles: mine over 3.1 million t LCE of lithium every year, for 20 years.

almost x20 the size of today's lithium market



The rise of lithium thus means taking today's market size and multiplying it by 20. This is going to require about 60 to 100 new lithium mines to be built, starting now, and operating for +20 years. We need to get started!

So when I talk about the rise and fall of lithium – the title of this presentation – this is what I mean. Massive investments are need to mine the lithium we need. Then, once we have enough, we need to move to a sustainable recycling market. Each mine or Gigafactory could be converted into a recycling plant, for example.

Once we've mined it all, we can emulate the Pb-acid battery industry, and recycle 99% of the material, at a profit. It will also help make EV's cheaper in the long run. Did you know that the lead-acid battery of today's vehicles cost about 1/3 of any other component of a car, on a $/kg basis? That's because it is a lot easier to produce a finished product out of worn, refined material, than it is to mine the material from scratch. Physics and process economics are linked!

TECHNOLOGICAL CHANGE

As the lithium industry matures into a large commoditized market, technological change will be needed to keep pace with the scale, and overall footprint of extracting lithium. Let me highlight a few of the necessary changes I would like to see:

- Move the entire industry off fossil fuels. Period. Solar is cheap now, and a safer bet than any fossil fuel, including natural gas. Apple and Google are doing it, why can't a mining industry do it?

- We can provide an example for other sectors of the mining industry.
  - To become safer, cheaper, and less reliant on fossil fuels.
  - In fact, we can spearhead the change in public perception and show how mining can be a clean business.

- Furthermore, we should not build on the assumption that fossil fuels will be cheap, abundant, and accessible.

$LiOH \cdot H_2O$

Another change that needs to happen:

Lithium process plants should make **LiOH directly**

- Best battery chemistries – Ni heavy – require hydroxide.
- Avoid the costly carbonate intermediate.
- To suggest that is cannot be done, or that is it not economical today is defying first-principles physics.

Brine processing

Higher Yields - Less Dependent on Climate

Brine processes are going to need to get better at extraction yields.

- Today's 30-50% yields can and should be improved upon. I think there is a pathway toward +90% recovery rates from most lithium deposits.
- Increasing yields also increases accessible resource size of any given deposit.
- Evaporation ponds can work on some brine resources, but not all. To unlock the full potential of undeveloped, yet rich, lithium brines, alternative flowsheets will be required compared to today's approach.
- This could include, for example, SX that is being developed in Israel, where extraction yields are very high indeed.
- Ore upgrading technologies should be advanced and showcased for rocks and clays.

Rock processing

Better Energy Sourcing - Simplified Processing

It's no secret that hardrock deposits operate at higher cash costs than today's brine projects. Yet, they are essential to the industry's growth and will be profitable for the foreseeable future.

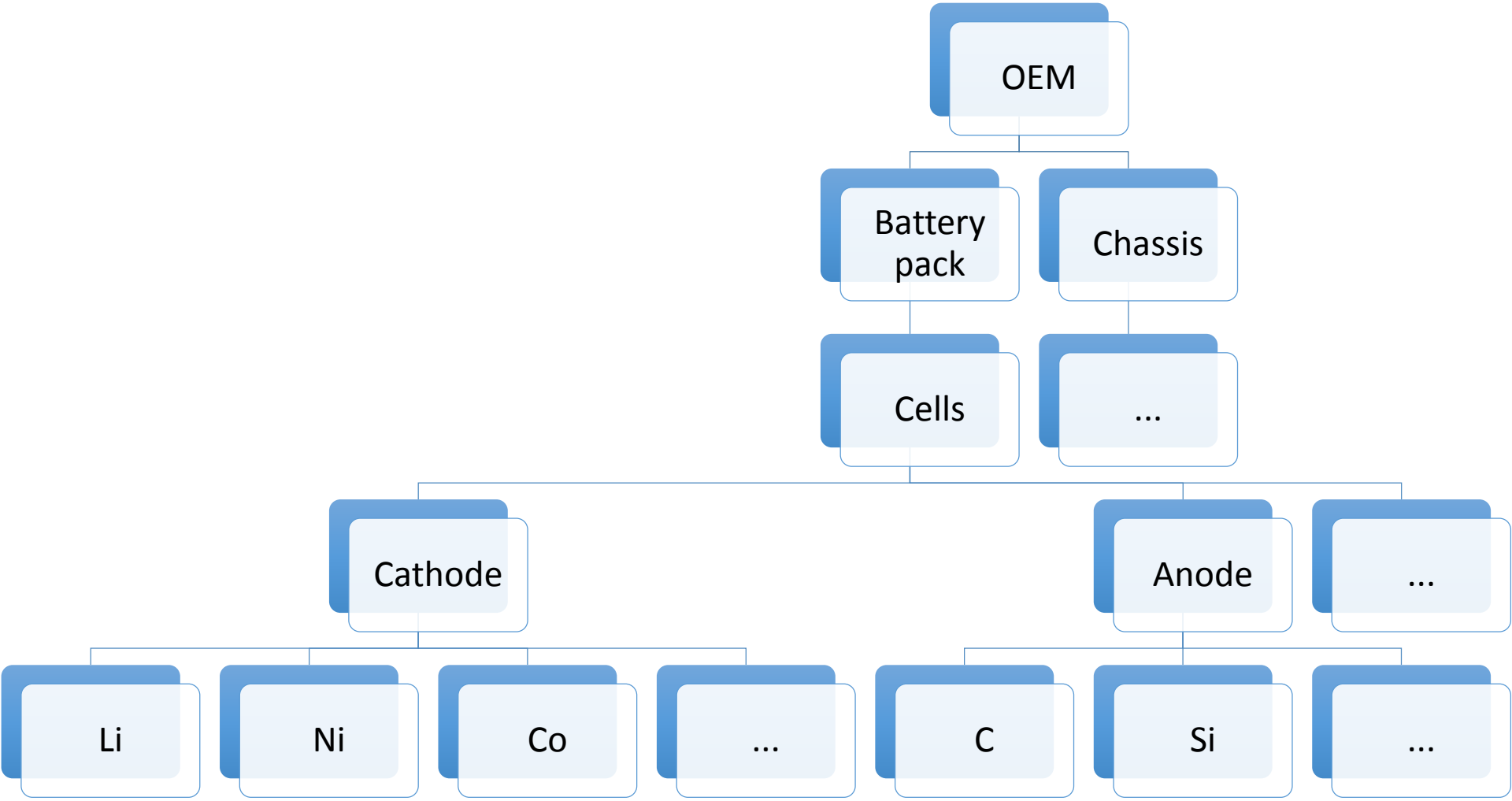
Hardrocks are going to need to leverage cheaper, and cleaner, energy sources.

- Today's operations in Australia, for example, could be more profitable, and cleaner, if ore concentrate was processed at the mine site, with renewable energy sources. There should be no need to transport hardrock, with all its deadweight, across oceans for down-stream processing. Even if the incremental costs of transport are low, the environmental costs are high.
- Today's processes can and should be more efficient and streamlined.

The process for mining hardrocks should be simplified.

- Again, LiOH should be made directly from leached solutions of Li2SO4 that comes from spodumene rock.
- Also, some deposits are low grade, but are found in the tailings of mines that exploit the ore for other materials. This will be a low cost solution to dealing with what is otherwise waste.

Vertical integration



Vertical integrations

- At some point, parts of the EV and battery supply chain should vertically integrate.
- Downstream cell factories could be built on top of mines, for example.
- Cathode manufacturers can consolidate upstream processes and synergize on water, energy, and consumable commonalities.
- That is the most efficient way to process materials into finished products.

Alternative sources

Brine

Hard rock

Clay

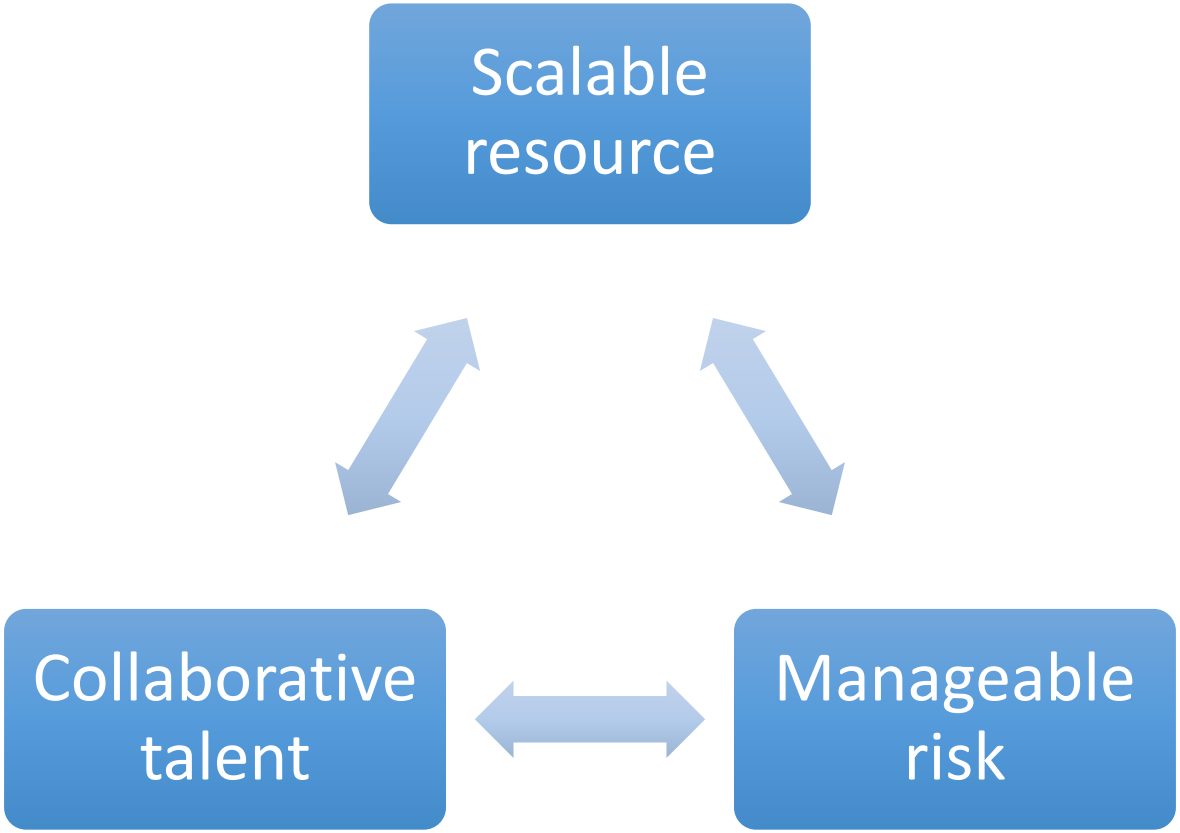
Clay deposits are going to be unlocked, with low-cost low-footprint processes.

- For example, LAC, the company I am now part of, is developing our clay based resource in Nevada, with promising new approaches to processing.

These basic technological changes are possible, and should be done. Producers will be more profitable, the carbon footprint reduced, and the footprint of the industry will be smaller.

- So, to reiterate, the technology changes I see happening include:
- Adoption of low-cost renewable energy sourcing.
- A move toward direct LiOH production.
- More efficient, reliable methods for extracting lithium from brines and hard rocks.
- Different forms of vertical integration, where efficiencies are maximized and waste is minimized.
- Broadening the commercial sources of lithium to include clay resources.

How best to invest in lithium?



INVESTMENT THESIS

So, let's get to the question I know you are all dying to address: how do you best invest in lithium? Which projects will provide the best returns at the lowest possible risk, as fast as possible?

Well, here is the criteria:

- You need a project with good resource quality and size
  - Think in Gigafactory increments: projects should strive for scaleable potential. For example, exploration projects should build the economics of a plant with scales that approach or exceed 50 ktpa LCE. With lifetimes of 20-plus years.
  - Grade and quality of resource needs to translate into cost-competitive processing. It's got to survive market price down-turns. I know this is mining 101, but sometimes people forget the basics in the hype of opportunity.
- Lowest risk execution factors
  - Access to infrastructure. It's important to be close to roads, rail, sea ports, etc.
  - Access to low-cost sustainable energy. Hydropower is ideal: it's scalable, reliable, and cheap. Wind and solar costs continue to fall, and should be leveraged over the volatility of fossil fuels.
  - Workable geology, water access, etc.
- Healthy politics, jurisdiction. Or at least, manageable ways to shelter a project from the risks.

- Last, but not least, you need to invest in the right teams. The best teams show:
  - Leadership who believes in the mission of delivering lithium in the most sustainable way possible. The mission should not be intrinsically about profit: profit should be the result, not the goal. You need teams that believe and own their mission.
  - Technical leadership with focus on practical, realistic, and innovative approaches.
  - Culture of risk management, partnerships, collaboration. Invest in those that seek to bridge and build ways forward. Beware of smoke and mirrors.

A Good project will involve less than $1000 investment per t LCE being mined. So if we need to mine around 60 million t LCE to electrify the world's transpiration system, that means this industry is going to need a total of about $60B investment. Just over 1/10th of such an investment would be enough to electrify every car in North America. **Let's get started!**

Take-away

- **Electrification of transport is a reality**
- **Lithium market size may grow by a factor of 20**
- **$700 to $1000 of capital is required per t LCE**
- **Investable projects are**
  - Scalable
  - Risk-manageable
  - Built on collaborative talent
- **Unprecedented investment opportunity**

Thank you