WEBVTT

1 "Marina Astitha (she,her)" (2769029632)
00:00:01.110 --> 00:00:07.710
Good afternoon. Everybody I'm very proud to have doctor Mark Jacobson with us today.

2 "Marina Astitha (she,her)" (2769029632)
00:00:07.710 --> 00:00:13.169
To give the seminar transitioning to 100% of clean, renewable energy.

3 "Marina Astitha (she,her)" (2769029632)
00:00:13.169 --> 00:00:23.880
For the whole country, maybe the whole world, but just for Connecticut. Dr Jacobson is a professor of civil environmental engineering at Stanford University.

4 "Marina Astitha (she,her)" (2769029632)
00:00:23.880 --> 00:00:31.170
And I will take probably more than half an hour to read all the prizes and accolades that he has received over the years.

5 "Marina Astitha (she,her)" (2769029632)
00:00:31.170 --> 00:00:35.220
Textbooks and and a lot of lot of other.

6 "Marina Astitha (she,her)" (2769029632)
00:00:35.220 --> 00:00:40.350
Recommendations and prices, the only 1 I would love to mention is.

7 "Marina Astitha (she,her)" (2769029632)
00:00:40.350 --> 00:00:47.550
The 1, the price from the National Academy of sciences in 2015.

8 "Marina Astitha (she,her)" (2769029632)
00:00:47.550 --> 00:00:59.155
For his work on pushing everybody to 100% move to wind and solar energy and new appointments in general. So, Mark thanks so much for doing this.

9 "Marina Astitha (she,her)" (2769029632)
00:00:59.155 --> 00:01:07.165
Um, love to hear from you and learn from your experience and teach us how to do that. do that

10 "Mark Jacobson" (1023545600)
00:01:07.645 --> 00:01:21.055

All right, thank you very much Marina for inviting me, and I'm happy to present this um, basically our work on transitioning States and countries and cities and towns to 100% renewable energy for all purposes,

11 "Mark Jacobson" (1023545600)
00:01:21.055 --> 00:01:27.355
and we've been working on this since 2009, the actual plans and of course, I've been trying to. course i've been trying to

12 "Mark Jacobson" (1023545600)
00:01:27.470 --> 00:01:42.195
Studying air, pollution and climate problems, um, since about 1989 but, um, so there are 3. I'm motivated by 3 major issues that I'm trying to address here. Um, when is air pollution the other is global warming. The 3rd is energy insecurity.

13 "Mark Jacobson" (1023545600)
00:01:42.195 --> 00:01:43.425
energy insecurity

14 "Mark Jacobson" (1023545600)
00:01:44.040 --> 00:01:56.100
So, fossil fuel and biofuel air pollution, worldwide causes about 7Million deaths and hundreds of millions more illnesses each year. Um, based on statistical cost of life and morbidity. That's.

15 "Mark Jacobson" (1023545600)
00:01:56.215 --> 00:02:10.825
Rounds up to about 30Trillion dollars per year. Uh, right now global warming is expected to cost on the order of 30Trillion dollars per year by 2050 and fossil fuels are limited resources they will run out at some point, and that will result in energy energy.

16 "Mark Jacobson" (1023545600)
00:02:10.825 --> 00:02:16.015
Uh, price, instability, economic instability. uh price instability economic instability

17 "Mark Jacobson" (1023545600)
00:02:16.100 --> 00:02:30.105
Political and social instability as well there are other types of energy security problems, including the fact that some countries have control of energy of other countries and in times of conflict, as you can see now, in Europe that results in, uh,

18 "Mark Jacobson" (1023545600)
00:02:30.405 --> 00:02:36.075
scarcity and energy pricing stability as well, in addition there are some countries that.

19 "Mark Jacobson" (1023545600)
00:02:36.100 --> 00:02:47.735
You have to transport fuels over long distance, like island countries and so the cost of energy in those countries is very high and so that's another type of energy. So that's another type of energy and security. Anyway.

20 "Mark Jacobson" (1023545600)
00:02:47.735 --> 00:02:52.114
These are all drastic problems that require immediate solution solutions.

21 "Mark Jacobson" (1023545600)
00:02:52.500 --> 00:03:01.170
So our idea has always been well, let's electrify all energy and provide that electricity with, from clean, renewable sources.

22 "Mark Jacobson" (1023545600)
00:03:01.675 --> 00:03:11.455
And just to put it into context, energy is responsible for about 90% of air pollution worldwide and about 75% of greenhouse gas emissions.

23 "Mark Jacobson" (1023545600)
00:03:11.665 --> 00:03:20.425
And so we also want to address non energy emissions as well, which are mostly biomass burning. mostly biomass burning

24 "Mark Jacobson" (1023545600)
00:03:20.730 --> 00:03:29.425
Uh, also, and which results in permanent deforestation also methane from, like, rice patties, landfills,

25 "Mark Jacobson" (1023545600)
00:03:29.815 --> 00:03:40.465
the digestive tracks of cattle and sheep and maneuver and also nitrous oxide emissions from fertilizers and also Halo gen emissions from, uh.

26 "Mark Jacobson" (1023545600)
00:03:40.730 --> 00:03:41.820
For.

27 "Mark Jacobson" (1023545600)
00:03:41.820 --> 00:03:50.545
Used to be chlorofluorocarbon, but now they're substitutes. So those are, you know, those emissions have to be addressed as well but for energy, I'm going to focus on here.

28 "Mark Jacobson" (1023545600)
00:03:50.575 --> 00:04:01.795
Well, for transportation, we'd go to battery electric vehicles, uh, for most transportation with some hydrogen fuel cell vehicles, for long distance, heavy transport for buildings. We would get.

29 "Mark Jacobson" (1023545600)
00:04:02.505 --> 00:04:16.125
For heating and cooling buildings, we've got an electric key pumps for individual buildings and then district heating and cooling for when you have, um, high, dense industrial or high density cities, for example, and even for district, heating and cooling.

30 "Mark Jacobson" (1023545600)
00:04:16.125 --> 00:04:21.225
We use heat pumps to raise the temperature of hot water and lower the temperature of cold water.

31 "Mark Jacobson" (1023545600)
00:04:21.820 --> 00:04:25.260
Use some geothermal and solar heat for district heating as well.

32 "Mark Jacobson" (1023545600)
00:04:25.615 --> 00:04:35.365
For industry, for high temperature processes. We've got an electric arc, furnaces, induction, furnaces, resistance, for instance, electric, heaters, electron beam heaters as well as heat pumps.

33 "Mark Jacobson" (1023545600)
00:04:35.635 --> 00:04:44.545
Um, and these are these are all for replace fossil fuels for heating right now and all the electricity for and heat for all these.

34 "Mark Jacobson" (1023545600)
00:04:45.260 --> 00:04:48.675
Technologies with, and appliances would be from wind water and solar.

35 "Mark Jacobson" (1023545600)
00:04:48.675 --> 00:05:02.535
So on shore and offshore wind, electricity, solar, photovoltaic, electricity, concentrated, solar, power, electricity, geothermal, electricity and geothermal heat, hydro, electricity and tidal wave electricity and I mentioned solar heat as well.

36 "Mark Jacobson" (1023545600)
00:05:03.089 --> 00:05:09.629

So, we'd also need storage for the windows and all that blow. The sun doesn't know we signed.

37 "Mark Jacobson" (1023545600)
00:05:09.714 --> 00:05:18.054
And we already have many types of storage technologies, concentrated, solar power storage. We have Hydro electric. Sorry pumps, hydro electric storage.

38 "Mark Jacobson" (1023545600)
00:05:18.084 --> 00:05:24.984
We have existing hydroelectric dam batteries, flywheels, compressed, air, storage, gravitational storage of solid masses.

39 "Mark Jacobson" (1023545600)
00:05:25.469 --> 00:05:33.239
And then, um, hydrogen storage for you, some fuel cells for grid electricity. So these are all existing technologies.

40 "Mark Jacobson" (1023545600)
00:05:33.239 --> 00:05:41.274
For heating and cooling storage, we'd use water tanks obviously, which are the most common types of hot and cold storage. Today.

41 "Mark Jacobson" (1023545600)
00:05:41.454 --> 00:05:48.804
There's ice storage for cold and underground boreholes water prefers for heat storage and also storing heat and building materials.

42 "Mark Jacobson" (1023545600)
00:05:49.259 --> 00:06:01.494
And then there's also hydrogen for non great applications, uh, such as steel, manufacturing, ammonia, manufacturing, um, and for transportation. So, these are all existing technologies.

43 "Mark Jacobson" (1023545600)
00:06:01.494 --> 00:06:08.994
In fact, I would argue, we have 95% of all the technologies we need the ones we don't have are like, hydrogen fuel. So long distance. long distance

44 "Mark Jacobson" (1023545600)
00:06:09.259 --> 00:06:13.499
Craft and chips, for example. Uh, but we have pretty much everything else.

45 "Mark Jacobson" (1023545600)
00:06:14.034 --> 00:06:21.774

Um, now you've heard a lot about hydrogen, so I just want to summarize my views about what are good and bad sources and uses of hydrogen.

46 "Mark Jacobson" (1023545600)
00:06:22.254 --> 00:06:31.524
So, the only good hydrogen is green hydrogen, which is from wind water, solar electricity and the bad hydrogen is any hydrogen from natural gas.

47 "Mark Jacobson" (1023545600)
00:06:31.769 --> 00:06:39.114
So, naturally, so hydrogen from natural gas 96% of all hydrogen today is produced from natural gas and that's just referred to as great hydrogen.

48 "Mark Jacobson" (1023545600)
00:06:39.114 --> 00:06:51.684
If you try to add carbon capture to natural to the hydrogen production from natural gas that's referred to as blue hydrogen. And we argue that is just as well. as well

49 "Mark Jacobson" (1023545600)
00:06:51.769 --> 00:06:56.789
You know, it's almost as bad as gray, hydrogen, and in terms of air pollution, it's actually worse.

50 "Mark Jacobson" (1023545600)
00:06:56.789 --> 00:07:09.414
And you also need a lot more infrastructure so it's worse in terms of infrastructure. Um, and so just not useful at all. Uh, black and brown hydrogen are from coal. Those are non starters pink hydrogen is from nuclear electricity.

51 "Mark Jacobson" (1023545600)
00:07:09.714 --> 00:07:16.704
We are not proposing to expand nuclear power at all and in fact, it will be phased out. So There'll be no nuclear nuclear powers.

52 "Mark Jacobson" (1023545600)
00:07:16.789 --> 00:07:19.559
We don't want to waste existing nuclear.

53 "Mark Jacobson" (1023545600)
00:07:19.704 --> 00:07:32.484
Or on a hydrogen production, when it's best combined with wind and solar, which are intermittent. So when the wind, when you have too much wind or solar, it's good to use that winter solar to produce hydrogen, rather than waste base load, nuclear on it.

54 "Mark Jacobson" (1023545600)

00:07:32.874 --> 00:07:39.474
Turquoise hydrogen comes from, comes from nothing and again from net for gas and we don't want that um.

55 "Mark Jacobson" (1023545600)
00:07:39.559 --> 00:07:54.119
So, what would we want to use hydrogen for as I mentioned long distance aircraft ships also, trains, trucks, military vehicles. These are long distance, trains and trucks and military vehicles, using fuel cells, only also ammonia production and steel manufacturing.

56 "Mark Jacobson" (1023545600)
00:07:54.324 --> 00:08:09.084
And in remote microgrids for a combination of electricity and heat, but also, I think that's even best combined with batteries. And then some great electricity combined with batteries, hydrogen alone for good. Electricity is not good.

57 "Mark Jacobson" (1023545600)
00:08:09.294 --> 00:08:14.004
It's just not very efficient at all. But there are some cases, some regions of the.

58 "Mark Jacobson" (1023545600)
00:08:14.119 --> 00:08:26.219
We found that using mostly batteries, but some hydrogen fuel cells actually reduces the cost of energy compared to batteries alone. Uh, but in most places, just batteries alone is sufficient for good electricity.

59 "Mark Jacobson" (1023545600)
00:08:26.219 --> 00:08:29.729
And bad use of hydrogen or all.

60 "Mark Jacobson" (1023545600)
00:08:29.964 --> 00:08:43.674
Vehicle transport, that's not long distance heavy transport, like passenger vehicles using it to heat buildings. Um, burning it. It's just not as efficient as heat pumps for heating buildings. Um, and then most cases grid electricity. Okay.

61 "Mark Jacobson" (1023545600)
00:08:43.674 --> 00:08:46.224
So also in our plans, we do not include.

62 "Mark Jacobson" (1023545600)
00:08:46.769 --> 00:08:55.829
Several things, we don't include carbon capture, direct air, capture small module of nuclear reactors, bio energy, non, hydrogen, electro fields.

63 "Mark Jacobson" (1023545600)
00:08:55.829 --> 00:09:08.969
And your engineering, or, as I mentioned blue hydrogen um, so, carbon captures basically, when you're out of equipment to try to suck out the from exhaustive, what's their coal fired power plant?

64 "Mark Jacobson" (1023545600)
00:09:08.969 --> 00:09:18.594
There's a huge energy penalty to do that or 30. let's say you put carbon capture equipment on a coal plant. Well, 30% of the electricity from the coal plant is needed to run the carbon capture equipment.

65 "Mark Jacobson" (1023545600)
00:09:18.594 --> 00:09:28.794
So, in other words, you'll need 30 more coal to run carbon capture equipment that means 30% more mining, 30%, more air pollution because you don't reduce any. don't reduce any

66 "Mark Jacobson" (1023545600)
00:09:28.969 --> 00:09:34.319
Pollutants with carbon capture, in fact, because you need more coal now you have 30% more.

67 "Mark Jacobson" (1023545600)
00:09:34.319 --> 00:09:46.764
In the mining process, and also in the combustion process so there's more air pollution, there's more mining, there's more fossil infrastructure with carbon capture and you hardly reduce any, uh, carbon dioxide.

68 "Mark Jacobson" (1023545600)
00:09:47.484 --> 00:09:54.294
Because they well, 1st of all the capture efficiencies not 90%. It's, it's anywhere the actual plants today are anywhere from 20%. twenty percent

69 "Mark Jacobson" (1023545600)
00:09:54.319 --> 00:09:56.489
To about 75%.

70 "Mark Jacobson" (1023545600)
00:09:56.489 --> 00:10:03.419
Well, the other problem is, let's say you use renewable energy to power the carbon capture equipment.

71 "Mark Jacobson" (1023545600)
00:10:03.419 --> 00:10:09.389

So, if you use renewable energy, just a power, carbon capture equipment, all you're reducing is sub.

72 "Mark Jacobson" (1023545600)
00:10:09.389 --> 00:10:15.539
You're not reducing any air pollution mining, or fossil infrastructure however, use the same renewable energy.

73 "Mark Jacobson" (1023545600)
00:10:15.539 --> 00:10:23.549
To replace the coal plant, you're not only reducing more then you would with the carbon capture.

74 "Mark Jacobson" (1023545600)
00:10:23.549 --> 00:10:37.349
Equipment your, Ah, powering, but you're also eliminating the air pollution from the coal plant. You're eliminating the mining from the coal plant, and the infrastructure from the coal plant. So the social cost benefit of replacing.

75 "Mark Jacobson" (1023545600)
00:10:37.349 --> 00:10:51.354
A call with renewables is much higher on the order, you know, factory anywhere from 5 to 10 higher than using, uh, renewable energy to run power,

76 "Mark Jacobson" (1023545600)
00:10:51.384 --> 00:10:52.794
carbon capture equipment just to take out the.

77 "Mark Jacobson" (1023545600)
00:10:53.759 --> 00:10:57.564
And what? And then, what do you do with the once? It's captured?

78 "Mark Jacobson" (1023545600)
00:10:57.954 --> 00:11:09.744
Well, 75% of the worldwide that's captured today is used for enhanced oil recovery and that just results in 40% of the that's captured going, right back to the air immediately, because that process involves binding.

79 "Mark Jacobson" (1023545600)
00:11:09.744 --> 00:11:13.674
The and the oil to make it less dense and bring it to. bring it to

80 "Mark Jacobson" (1023545600)
00:11:13.759 --> 00:11:26.594

The surface, and when that happens, then 30% of the gets lost just released from that process. And 10% of the is lost, uh, because 1st of all, you need more energy to pipe the to the field.

81 "Mark Jacobson" (1023545600)
00:11:26.954 --> 00:11:29.504
And then there's some leaks along the way. the way

82 "Mark Jacobson" (1023545600)
00:11:29.969 --> 00:11:37.229
Anyway, so, tell us about 40% lost from heswall recovery plus you have more oil that you're burning, creating more air pollution.

83 "Mark Jacobson" (1023545600)
00:11:37.254 --> 00:11:49.584
Now, the other way to what's the other thing that you can do is W, well, 4 is to produce electric fields non hydrogen, electric fields. So those are fields to replace gasoline.

84 "Mark Jacobson" (1023545600)
00:11:49.584 --> 00:11:56.904
So you use and some other chemicals and a lot of energy to re, produce gasoline. And then you burn that gas link, you burn that fuel.

85 "Mark Jacobson" (1023545600)
00:11:57.229 --> 00:12:04.199
So, you produce air pollution, just like you do burning gasoline and you have this inefficiency of the carbon capture.

86 "Mark Jacobson" (1023545600)
00:12:04.199 --> 00:12:16.134
And you need a lot of energy to produce the electric field. So that whole process is really inefficient, very polluting, and electro fuels, carbon capture, and also direct air capture all being pushed by the fossil fuel industry.

87 "Mark Jacobson" (1023545600)
00:12:16.464 --> 00:12:23.934
Uh, this is just to keep themselves relevant and same with blue hydrogen. Um, why not small module reactors? Well, large.

88 "Mark Jacobson" (1023545600)
00:12:24.199 --> 00:12:26.159
They take.

89 "Mark Jacobson" (1023545600)
00:12:26.159 --> 00:12:30.149

17 to 21 years, and then realized markets between planning and operation.

90 "Mark Jacobson" (1023545600)
00:12:30.149 --> 00:12:38.789
The vocal plants in Georgia are the only 2 in the us being built are on, you're 17 and 18, and they just are just starting to be tested right now.

91 "Mark Jacobson" (1023545600)
00:12:38.789 --> 00:12:49.499
Uh, there like 4 plants in Europe that are between 17 and 21 years, and they cost, like, the vocal plan in Georgia is cost 34Billion dollars.

92 "Mark Jacobson" (1023545600)
00:12:49.854 --> 00:13:00.354
And that's and for an estimate for 2.3 gigawatts of, uh, of nameplate capacity. So that's about 15.2 dollars a watt that compares to 1 dollar a watt for a new Windows solar.

93 "Mark Jacobson" (1023545600)
00:13:00.354 --> 00:13:08.304
When we looked at, when we look at the levelized cost of energy, that's about the nuclear is about 8 times higher than new wind or solar. new wind or solar

94 "Mark Jacobson" (1023545600)
00:13:09.149 --> 00:13:16.889
And it takes wind or solar about 1 to 3 years between planning and operation. So why would you want to wait another 15 to 18 years?

95 "Mark Jacobson" (1023545600)
00:13:16.889 --> 00:13:27.269
Between planning and operation for something that cost 8 times higher it just makes no sense. We need to solve 80% of the climate and air pushing problems. We face by 2030.

96 "Mark Jacobson" (1023545600)
00:13:27.269 --> 00:13:33.389
And if you have a technology that if you start planning today won't even be ready until 2042 completely useless.

97 "Mark Jacobson" (1023545600)
00:13:33.684 --> 00:13:41.634
And that's ignoring the fact that nuclear has all these other issues meltdown risk 1, and a half percent of all reactors ever built up melted down weapons.

98 "Mark Jacobson" (1023545600)
00:13:42.234 --> 00:13:53.304

Proliferation risks are 5 countries that have developed weapons secretly under the guise of civilian, nuclear energy, or research programs and also there's underground uranium, uh, mining.

99 "Mark Jacobson" (1023545600)
00:13:53.389 --> 00:13:54.644
Cancer risk,

100 "Mark Jacobson" (1023545600)
00:13:55.034 --> 00:14:09.884
there's the waste issue you have to store radioactive waste for 200,000 years and there's the fact that nuclear produces not only because when you have to refine uranium continuously over its life and that takes energy but also there's water vapor emissions from nuclear

101 "Mark Jacobson" (1023545600)
00:14:09.884 --> 00:14:13.184
plants. And there's heat emissions directly when you. when you

102 "Mark Jacobson" (1023545600)
00:14:13.389 --> 00:14:18.839
For all the emissions, plus the opportunity cost emissions of having to wait around to put up the nuclear.

103 "Mark Jacobson" (1023545600)
00:14:18.839 --> 00:14:26.099
There was about 9 to 37 times the emissions per kilowatt hour generated for nuclear versus when.

104 "Mark Jacobson" (1023545600)
00:14:26.099 --> 00:14:39.989
So, it's not either queen or, uh, helpful in solving our problems. Now small molecule reactors have the same problems as big ones. They have to lay problems already. We're not even expected to be ready until 2030.

105 "Mark Jacobson" (1023545600)
00:14:40.194 --> 00:14:48.534
And that's just that's just testing in their cost issues are unknown, but the costs keep going up. Every estimate, keeps going up weapons.

106 "Mark Jacobson" (1023545600)
00:14:48.534 --> 00:14:59.904
Proliferation is going to be a greater issue with small module reactors, because it's easier to ship them around the world through different countries that don't have nuclear right now a meltdown risk is unknown uh, underground uranium.

107 "Mark Jacobson" (1023545600)
00:14:59.989 --> 00:15:07.109
Finding risk is the same missions at risk is the same so there's no benefit of small molecule reactors.

108 "Mark Jacobson" (1023545600)
00:15:07.109 --> 00:15:12.449
Bio energy, you burn biofilms or biomass and so that creates air pollution.

109 "Mark Jacobson" (1023545600)
00:15:12.449 --> 00:15:21.119
There's a lot of carbon, and a lot of energy goes into producing the bio energy. And so the carbon benefit is is pretty miniscule. If any.

110 "Mark Jacobson" (1023545600)
00:15:21.119 --> 00:15:29.819
And and when you're talking about bio feels like corn ethanol or solid biodiesel, or we're talking about huge amounts of land and.

111 "Mark Jacobson" (1023545600)
00:15:29.819 --> 00:15:33.869
The land requirements is just it's an astronomical I mean.

112 "Mark Jacobson" (1023545600)
00:15:34.164 --> 00:15:47.574
You know, photosynthesis. This is only 1% efficient, whereas photo solar photovoltaic are 20% efficient. So you get 20%, 20 times more energy over the same land by putting a solar cell than you do growing a Biofilm crop.

113 "Mark Jacobson" (1023545600)
00:15:47.574 --> 00:15:52.824
And if you consider that electric vehicles are 4 times the efficiency. times the efficiency

114 "Mark Jacobson" (1023545600)
00:15:53.069 --> 00:16:06.179
As gasoline vehicles that means solar PV powering electric vehicle can go 80 times further for the same land as a biofuel powering a internal combustion engine vehicle.

115 "Mark Jacobson" (1023545600)
00:16:06.179 --> 00:16:14.999
It just makes no sense whatsoever to use. Bioenergy. Geo engineering is basically 1 of the types of engineering is spraying particles of the stratosphere.

116 "Mark Jacobson" (1023545600)
00:16:14.999 --> 00:16:19.254
To block sunlight while this does not stop 1 bit of fossil fuel emissions or air pollution,

117 "Mark Jacobson" (1023545600)
00:16:19.254 --> 00:16:32.844
death and so those continuing continue to grow because people could become complacent also blocking the sun reduces photosynthesis to the surface of that can create crop failures in some parts of the world that can create starvation.

118 "Mark Jacobson" (1023545600)
00:16:32.844 --> 00:16:34.914
So there are unintended consequences. The particles are.

119 "Mark Jacobson" (1023545600)
00:16:34.999 --> 00:16:41.669
Come down as well creating more air pollution worldwide, just ridiculous. Uh, by the way these photographs.

120 "Mark Jacobson" (1023545600)
00:16:42.174 --> 00:16:56.784
Well, the 1 on the left is from 958, Los Angeles in the winter, and the right is a photograph I took from the bottom it's photograph I took a few weeks ago from Los Angeles, and just I want to point out how air pollution is still a significant problem, even in California and Los Angeles.

121 "Mark Jacobson" (1023545600)
00:16:56.994 --> 00:16:58.254
california and los angeles

122 "Mark Jacobson" (1023545600)
00:16:58.979 --> 00:17:02.819
I mean, in the U s about 80,000 people died here from air pollution.

123 "Mark Jacobson" (1023545600)
00:17:02.819 --> 00:17:15.419
But this is so if you have any technology that's going to keep allowing air pollution or increase it, like, carbon capture, direct air, capture bio energy, electro, fuels, geo engineering.

124 "Mark Jacobson" (1023545600)
00:17:15.419 --> 00:17:29.484
Blue hydrogen, there's all increase air pollution, so we do not want to increase air pollution so we do not want those fields just off from the get go, stay away from it. Um, okay so let's move on to talk about uh, both.

125 "Mark Jacobson" (1023545600)
00:17:29.514 --> 00:17:35.244
I just want to show some examples of, uh, district heating systems. So this is actually our university.

126 "Mark Jacobson" (1023545600)
00:17:35.419 --> 00:17:38.939
Uh, is now on well, it's been since 2016.

127 "Mark Jacobson" (1023545600)
00:17:38.964 --> 00:17:48.024
On this, uh, renewable district heating system, where so it used to be that 80% of the campus electricity and heat was provided by natural gas Co generation plan.

128 "Mark Jacobson" (1023545600)
00:17:48.024 --> 00:17:58.854
That was all those in 2016 and replaced with this, these 2 chillers and a boiler and about 35 miles of hot water pipes and 35 miles of cold water pipes around the. of cold water pipes around the

129 "Mark Jacobson" (1023545600)
00:17:58.939 --> 00:18:01.859
Diversity to heat and cool buildings.

130 "Mark Jacobson" (1023545600)
00:18:02.244 --> 00:18:16.464
And heat pumps are used to raise the temperature of the heat for the hot water tank and lower the temperature of the cold for the cold water tank. The university purchased 10 megawatts of rooftop, solar and 150 megawatts, solar PV and 2 power plants in central Valley.

131 "Mark Jacobson" (1023545600)
00:18:16.464 --> 00:18:17.394
in central valley

132 "Mark Jacobson" (1023545600)
00:18:17.909 --> 00:18:21.179
So, 160 megawatts, total.

133 "Mark Jacobson" (1023545600)
00:18:21.179 --> 00:18:35.874
And with that, the university is effectively the 1st University in the world to be 100% renewable, not only for electricity, but also for heating and cooling and there are still some diesel generators for backup around the campus.

134 "Mark Jacobson" (1023545600)
00:18:35.874 --> 00:18:37.193
And there's still some. still some

135 "Mark Jacobson" (1023545600)
00:18:37.859 --> 00:18:45.899
Um, vehicles that are natural gas vehicles that are trying to get rid of those as well to go 100% renewable for transportation. And also for.

136 "Mark Jacobson" (1023545600)
00:18:45.899 --> 00:18:59.664
A backup generation, but just for your heating cooling is really effective. Well, 7% of the U. S. is subject to district heating right now. Um, this is district heating and cooling, which is 4th generation. Um, but there are more in northern Europe.

137 "Mark Jacobson" (1023545600)
00:18:59.664 --> 00:19:05.814
Europe sub countries are 50% distributing cause it's very common in many parts. many parts

138 "Mark Jacobson" (1023545600)
00:19:05.899 --> 00:19:19.439
The world, Here's another type of district heating system. This is seasonal heat storage underground. This is an Canada in 2004 and 552 homes built with the solar collectors on there.

139 "Mark Jacobson" (1023545600)
00:19:19.439 --> 00:19:28.949
On the rest of their garages on the top left and in the solar collectors is a glycol solution. So so during the summer, when the days are long.

140 "Mark Jacobson" (1023545600)
00:19:28.949 --> 00:19:40.349
The glycol solution heats up and his pipes, the building on the right where the heat is transferred to water. The water is then piped under this field where there are a bunch of U shaped pipes that go down about 30 meters.

141 "Mark Jacobson" (1023545600)
00:19:40.349 --> 00:19:44.519
And the heat is transferred to the soil and there's installation.

142 "Mark Jacobson" (1023545600)
00:19:44.519 --> 00:19:50.759
On the top and around the edge to keep that soil, uh, warm for up to 6 months.

143 "Mark Jacobson" (1023545600)

00:19:51.174 --> 00:20:02.664
And then in the winter, when the snow is on the ground, like, on the bottom left, the whole system is running in reverse and that those 52 homes are heated by this underground borehole storage 100% of their.

144 "Mark Jacobson" (1023545600)
00:20:02.664 --> 00:20:10.524
He just comes from the borehole storage and the cost of the storage itself is less than 1 dollar a kilowatt hour. I mean, that's. i mean that's

145 "Mark Jacobson" (1023545600)
00:20:10.759 --> 00:20:22.469
Storage, but compare that to battery storage is between 10,200 dollars a killer whatever. So, it's very inexpensive, um, storage and it provides 100 of the heat seasonally since long term energy storage.

146 "Mark Jacobson" (1023545600)
00:20:23.064 --> 00:20:37.524
Here's another type of long term energy, storage, called water, pit storage. Uh, this is in Denmark, they have this big swimming pool, like, structure, filled with water, covered with installation during the summer, or the solar collectors heat up that water.

147 "Mark Jacobson" (1023545600)
00:20:37.974 --> 00:20:42.444
And the heat is up to 80 to 80 degrees Celsius in the hot water.

148 "Mark Jacobson" (1023545600)
00:20:42.494 --> 00:20:57.104
Restored, um, through the year, but mostly till winter time, when the snow is on the ground and used to heat about 2800 homes, uh, in this town. So that's a waterfall storage to also seasonal. Um, this is ice storage.

149 "Mark Jacobson" (1023545600)
00:20:57.104 --> 00:21:02.444
Actually, Stanford had an ice cube under a building since 998 and during. nine hundred and ninety eight and during

150 "Mark Jacobson" (1023545600)
00:21:02.469 --> 00:21:09.809
In the night, when the electricity price was low, the electricity was used to produce the ice and then during the day on the summer, especially.

151 "Mark Jacobson" (1023545600)
00:21:09.809 --> 00:21:17.429

Instead of using air conditioning in the afternoon, which is when California electricity demand is highest, and you have blackout.

152 "Mark Jacobson" (1023545600)
00:21:17.429 --> 00:21:31.019
They ran water through the coils in the ice and the cold water was set to buildings to cool the building. So, this is like, electricity storage, except it's much cheaper. It's about 30 dollars a kilowatt hour. Um, effectively for the electricity storage.

153 "Mark Jacobson" (1023545600)
00:21:32.154 --> 00:21:46.194
What about individual buildings? So I'm going to talk about my own home in 2017. I built a new home that with no natural gas. It ran entirely on the solar on the rooftop while it is connected to the grids.

154 "Mark Jacobson" (1023545600)
00:21:46.194 --> 00:21:50.934
I don't want to say entirely, but in the annual averages entirely so there's 13. so there's thirteen

155 "Mark Jacobson" (1023545600)
00:21:51.019 --> 00:22:05.714
Point 6, kilowatts of solar PV on the roof. There are formed, uh, 1st, generation Tesla while now batteries in the garage and have electric vehicles for heating. I use what's called a Douglas mini split key pump air heater and air conditioner.

156 "Mark Jacobson" (1023545600)
00:22:06.119 --> 00:22:11.789
So there are each unit you just are each room has 1 of these units on the left.

157 "Mark Jacobson" (1023545600)
00:22:11.789 --> 00:22:23.784
And then there's other of their total of about 11 units and then so, 6 of them are connected to 1 of these units on the right and 5 of them are connected to another 1 of the units on the right? So this unit on the right?

158 "Mark Jacobson" (1023545600)
00:22:23.784 --> 00:22:31.674
It is basically a fan that exchanges air with the outside. Basically the idea is that well, he pumps they use 14th, the energy as natural gas. gas

159 "Mark Jacobson" (1023545600)
00:22:31.789 --> 00:22:38.279
And that's because they don't create he, they actually just move it from the outside to the inside or from the inside to the outside.

160 "Mark Jacobson" (1023545600)
00:22:38.844 --> 00:22:46.854
And there are no ducks. So you're not like sending heat around in ducks through the house. You're just it's it's there's a bunch of tubes.

161 "Mark Jacobson" (1023545600)
00:22:46.944 --> 00:22:58.104
Well, there's 1, there's a tube between each of the inside units, and the outside unit that contains coolant and it's really through a latent heat released through the evaporation and condensation of this.

162 "Mark Jacobson" (1023545600)
00:22:58.279 --> 00:23:07.409
And through, uh, change the pressure that you expand and contract, uh, gas to raise or lower the temperature.

163 "Mark Jacobson" (1023545600)
00:23:07.409 --> 00:23:13.464
That, uh, you get you transfer heat from the inside to the outside of the outside to the inside. So they're very efficient use.

164 "Mark Jacobson" (1023545600)
00:23:13.464 --> 00:23:27.144
14th energy is gas and there it costs about the same as a, as a regular, let's say, a gas gas unit throughout your house to heat and also plus air conditioning. Um, and then for. for

165 "Mark Jacobson" (1023545600)
00:23:27.409 --> 00:23:35.339
Her heating, I use it what's called a heat pump water heater. So, in this case, the heat is extracted from the air in the room that this water heater sits in.

166 "Mark Jacobson" (1023545600)
00:23:35.339 --> 00:23:43.319
And that mechanical room temperature goes down a couple of degrees, which is nice in the summer, because you can open the door and it's additional air conditioning for the house.

167 "Mark Jacobson" (1023545600)
00:23:44.124 --> 00:23:58.464
Um, but it just you again, it uses 14th, the energy is natural gas, and it works perfectly hasn't never broken down and I've had it, um, for 6 years now over 6 years for cooking. I use an electric induction cooktop.

168 "Mark Jacobson" (1023545600)

00:23:58.464 --> 00:24:03.234
Um, these are different from electric resistance. Serves, but they're. they're

169 "Mark Jacobson" (1023545600)
00:24:03.319 --> 00:24:12.449
They're very efficient and they work the heat water and half the time is natural gas. They operate well, there's an electric current running in the stove and you need.

170 "Mark Jacobson" (1023545600)
00:24:12.449 --> 00:24:20.969
An iron or stainless steel base for your pots and pans because you need something that is highly resistant.

171 "Mark Jacobson" (1023545600)
00:24:20.969 --> 00:24:25.409
Because the electric current in the stove, it induces the current.

172 "Mark Jacobson" (1023545600)
00:24:25.409 --> 00:24:37.074
To electric conduction induces occurrence in the base of the color of the pan and because the base of the part of the pan is resistant metal that current anticipated as heat in the base of the palm of their pants.

173 "Mark Jacobson" (1023545600)
00:24:37.074 --> 00:24:45.384
So the pot heats up, or the pen heats up, and it cuts the food evenly, but the stove itself doesn't get hot. It just gets warm.

174 "Mark Jacobson" (1023545600)
00:24:45.409 --> 00:24:50.429
Do the conduction of heat from the back to the stove so you can be boiling water.

175 "Mark Jacobson" (1023545600)
00:24:50.429 --> 00:25:03.629
And touch the stove, and you're not going to hurt your hand and because the stuff is just warm. So it's safe as well as he cooked evenly and it cooks quickly. And so there's very little disadvantage. I'm showing 1 of these units on the left.

176 "Mark Jacobson" (1023545600)
00:25:03.629 --> 00:25:10.829
Because, you know, that cost, you can plug that into your wall and that costs, like, 30 to 80 dollars.

177 "Mark Jacobson" (1023545600)

00:25:11.544 --> 00:25:26.244
And the reason it's so beneficial. Well, I mentioned 7Million people die from airports nature. Well, about, uh, 2.4Million are from indoor burning of bio fields and, uh, Donald dung and wood and other materials, uh, for home, heating and cooking.

178 "Mark Jacobson" (1023545600)
00:25:26.244 --> 00:25:30.564
And if you can replace your home heating. replace your home heating

179 "Mark Jacobson" (1023545600)
00:25:30.829 --> 00:25:32.459
Burning things with.

180 "Mark Jacobson" (1023545600)
00:25:32.459 --> 00:25:44.484
With the electric conduction, you know, cut off like this, you just plug it in. Well, of course, we need an electricity source. So communities that don't have electricity. This is where we need micro grids, which are like, solar and batteries, for example.

181 "Mark Jacobson" (1023545600)
00:25:44.814 --> 00:25:51.774
And then, but these, uh, induction cooktops they don't take much energy and you're not using very long in any case. And.

182 "Mark Jacobson" (1023545600)
00:25:52.259 --> 00:26:03.749
Yeah, so we can imagine for going worldwide to trying to transition the world. We'll need to address indoor burning and biofuels and cold. So this electric conduction is 1 way to go.

183 "Mark Jacobson" (1023545600)
00:26:03.749 --> 00:26:15.719
So, over the 1st, 5 years of energy use, I generated 120% of all my home and vehicle, uh, energy from a solar.

184 "Mark Jacobson" (1023545600)
00:26:15.719 --> 00:26:25.644
And I had no electric bill and no natural gas bill, or gasoline bill for those 5 years, and received an average of 860 dollars per year for the extra 20% of electricity that I sent back to the community choice.

185 "Mark Jacobson" (1023545600)
00:26:26.004 --> 00:26:35.274
Aggregation utility Silicon Valley clean energy, uh, for the extra electricity. And so I also avoided a gas hook up. a gas hook up

186 "Mark Jacobson" (1023545600)
00:26:35.719 --> 00:26:43.259
6,000 dollars, because my utility normally utility PG E who's in control of transmission distribution?

187 "Mark Jacobson" (1023545600)
00:26:43.259 --> 00:26:50.759
They would charge anywhere, depending on the size of your home from 3 to 8,000 dollars, just to hook up the gas to your property.

188 "Mark Jacobson" (1023545600)
00:26:50.759 --> 00:26:57.989
Gas pipes or another 2 to 15,000 dollars. I saved about 10,000 dollars there and then avoided all this, these bills.

189 "Mark Jacobson" (1023545600)
00:26:57.989 --> 00:27:08.039
So the overall payback time was 5 years. So I've, I've actually with subsidies without substances 10 years, but there are services available in the U. S. and California.

190 "Mark Jacobson" (1023545600)
00:27:08.039 --> 00:27:12.419
So, I've already paid back this whole system of solar and battery system.

191 "Mark Jacobson" (1023545600)
00:27:12.419 --> 00:27:17.189
With the savings and the solar warranty for 25 years. So for the next.

192 "Mark Jacobson" (1023545600)
00:27:17.189 --> 00:27:31.914
You know, basically, 20 years, it should be just free energy without subsidies still a 10 year payback time, which is amazing. Uh, given that you sold warranty for 25 years the solar is now, um, this is the hottest day of the year. year

193 "Mark Jacobson" (1023545600)
00:27:32.759 --> 00:27:43.919
Which was in 2020 or September 6 and the outside temperature was 106 degrees. I maintain the inside temperature at 77 degrees. So, on that day, a generated.

194 "Mark Jacobson" (1023545600)
00:27:43.919 --> 00:27:56.129
You said from the green to end, generate about 60 kilowatt hours of electricity. The blue during the day is that solar electricity being used for air conditioning mostly but some other stuff.

195 "Mark Jacobson" (1023545600)
00:27:56.129 --> 00:28:02.759
The blue at night is when the batteries kick in, and then the red is when the grid kicks in to provide some electricity but I.

196 "Mark Jacobson" (1023545600)
00:28:02.759 --> 00:28:07.739
I considered going 45 kilowatt hour so I sent an extra 15 kilowatt hours.

197 "Mark Jacobson" (1023545600)
00:28:07.739 --> 00:28:21.414
Back to the grid that day and this is a type of day where you have blackouts in California. So if if everybody well, if every house and building had its own solar battery storage system, then we would not have blackouts in California.

198 "Mark Jacobson" (1023545600)
00:28:21.444 --> 00:28:27.084
This is just simple truth. Because there's and if we have efficient homes, heat, pumps.

199 "Mark Jacobson" (1023545600)
00:28:27.809 --> 00:28:33.689
And, yeah, lights it, I mean, a lot to say, lots of say for energy efficiency.

200 "Mark Jacobson" (1023545600)
00:28:33.689 --> 00:28:47.579
But it's just, um, yeah, it's just so everything these technologies today are so good. I mean, they're so efficient. They're reliable. Nothing breaks down. I mean, even my lights, I've only D, lights for s, um, since.

201 "Mark Jacobson" (1023545600)
00:28:47.579 --> 00:28:56.039
Early 2017, so 6 years almost actually, it's been 6 years. Now. I have not had a single light bulb burn out in 6 years.

202 "Mark Jacobson" (1023545600)
00:28:56.039 --> 00:29:06.479
And the whole house is only do like, there's not a single label anywhere in the house that's gone out and they're just so efficient. And and they're amazing, you know.

203 "Mark Jacobson" (1023545600)
00:29:06.479 --> 00:29:16.109
Uh, amazing technologies today now, let's shift to talk about the whole world. Can we transition the world to 100 renewables for all of purposes?

204 "Mark Jacobson" (1023545600)
00:29:16.109 --> 00:29:20.399
So, we've done roadmap for 145 countries.

205 "Mark Jacobson" (1023545600)
00:29:20.399 --> 00:29:29.099
And so we've done each of the individual countries, but this shows results, when you sum up overall countries, the end use demand among all these countries.

206 "Mark Jacobson" (1023545600)
00:29:29.099 --> 00:29:33.299
For all purposes, we're 13.1Trillion Watts in 2018.

207 "Mark Jacobson" (1023545600)
00:29:33.299 --> 00:29:37.559
That's expected to go up to 2094 kilowatts in 2050.

208 "Mark Jacobson" (1023545600)
00:29:38.184 --> 00:29:53.094
But if we electrify all energy and provide the electricity with wind water, solar, we go down about 56% to 8.9. terrible. There are 5 reasons we go down. 1 is a battery electric vehicles and hydrogen fuel cell vehicles are more efficient than internal combustion engine vehicles. internal combustion engine vehicles

209 "Mark Jacobson" (1023545600)
00:29:53.639 --> 00:30:00.089
We use less energy for those electrified industry is slightly more efficient than internal combustion engine. Sorry?

210 "Mark Jacobson" (1023545600)
00:30:00.089 --> 00:30:08.129
And combustion industry, he pumps are more efficient for air, heating and water, heating and air conditioning. Then.

211 "Mark Jacobson" (1023545600)
00:30:08.129 --> 00:30:22.464
The current system, eliminating field mining. Well, mining of fossil fuels in uranium takes up 11.3% of all energy worldwide. We eliminate all that mining because when comes right to the turbine solar comes right to the panel.

212 "Mark Jacobson" (1023545600)
00:30:22.464 --> 00:30:28.104

So we don't have to mind fuels continuously. We still have mining for material. mining for material

213 "Mark Jacobson" (1023545600)
00:30:28.129 --> 00:30:28.889
Calls.

214 "Mark Jacobson" (1023545600)
00:30:29.394 --> 00:30:43.224
And so we're not eliminating natural landing here so that that's still exists. But this is for fuel mining, continuous for money. And then we have 6.6% reduction of energy needs due to energy efficiency improvements beyond business as usual. business as usual

215 "Mark Jacobson" (1023545600)
00:30:43.889 --> 00:30:53.999
So this graph shows, uh, the same thing, except in graphical form from 2020 to 2050 if we don't do anything, we follow the top line.

216 "Mark Jacobson" (1023545600)
00:30:53.999 --> 00:31:06.389
And business as usual line, but if we electrify all the energy and provided with wind water solar, we go down those 5 shades and colors to the 100 W. W line at 8.9. terabytes.

217 "Mark Jacobson" (1023545600)
00:31:06.389 --> 00:31:13.679
And then we'll provide that winter solar with an average of about 32% on Sherwin, 30% officer win, et cetera.

218 "Mark Jacobson" (1023545600)
00:31:13.679 --> 00:31:23.009
Of course, this is an average overall countries. Each country has its own mix and this shows an 80% transition by 2030 and 100 by 2050.

219 "Mark Jacobson" (1023545600)
00:31:23.009 --> 00:31:32.939
What we need though? Well, we need to as rapid as possible transition, but if we can get 80% by 2030, why not? 100% by 2035? So that's where this graph shows.

220 "Mark Jacobson" (1023545600)
00:31:32.939 --> 00:31:45.539
With the same end point at 2050 and so we do need to avoid 1.5 degrees, global warming and to avoid more air pollution tests that are occurring. We do need to transition as rapidly as possible.

221 "Mark Jacobson" (1023545600)
00:31:45.539 --> 00:31:49.169
So this shows, um.

222 "Mark Jacobson" (1023545600)
00:31:50.454 --> 00:31:54.084
That kind of the average mix in the world, and I show in the U. S.

223 "Mark Jacobson" (1023545600)
00:31:54.114 --> 00:32:09.084
and then we also did study for each individual region in the US, including the Northeast, which is the, which Connecticut is part of and this shows the, um, you know, the percentages for each.

224 "Mark Jacobson" (1023545600)
00:32:09.169 --> 00:32:12.119
For each of these regions, or or the world.

225 "Mark Jacobson" (1023545600)
00:32:12.119 --> 00:32:25.314
Um, well, if I look at the U. S, it's about 28% on Sherwin and 16 off shore 21% rooftop, PV, 31% utility PV, small amounts of CSP and geothermal about 3% hydro and all that exists already.

226 "Mark Jacobson" (1023545600)
00:32:25.314 --> 00:32:32.094
Actually, because our plans don't call for new hydro and then small amounts of title. hydro and then small amounts of title

227 "Mark Jacobson" (1023545600)
00:32:32.119 --> 00:32:34.694
Way of power, geothermal heat and solar heat.

228 "Mark Jacobson" (1023545600)
00:32:34.694 --> 00:32:48.674
There's also it's also going to we'll send you that, but these simulations actually, we didn't include it because we just generated all our heat from excess electricity and these simulations didn't even need the geothermal or sorry for the, the Northeast.

229 "Mark Jacobson" (1023545600)
00:32:49.154 --> 00:32:51.974
Uh, it's a little different mix less on Sherwin more.

230 "Mark Jacobson" (1023545600)
00:32:52.119 --> 00:33:06.934

For wind, uh, less rooftop PV, unless utility PV no CSP or geothermal they're only 13 States in the U. S. that have reasonable geothermal resources for electricity. And but 7% Hydro, which all exists by the way.

231 "Mark Jacobson" (1023545600)
00:33:06.934 --> 00:33:09.214
And then 20 minutes of total way power. power

232 "Mark Jacobson" (1023545600)
00:33:09.809 --> 00:33:21.149
So, it's going to be mostly a lot of offshore when they offer when resource off the East Coast, the U. S. is just an enormous. I mean, there's, you can power the entire U. S. with the offshore wind resource.

233 "Mark Jacobson" (1023545600)
00:33:21.149 --> 00:33:28.349
There so that's, um, but this again is just 1 possibility. Well, how much land would this all take out?

234 "Mark Jacobson" (1023545600)
00:33:29.484 --> 00:33:42.564
Well, average, we don't need new land for offshore wind or title wave power. We don't have new hydro and our plans. Rooftop. Pv does not take up new land. Geothermal is pretty small so it's just utility PV and and onshore wind.

235 "Mark Jacobson" (1023545600)
00:33:42.894 --> 00:33:48.324
Well, the onshore wind is spacing between wind turbines and that can be used for multiple purposes.

236 "Mark Jacobson" (1023545600)
00:33:48.349 --> 00:33:59.234
Is like farmland range, land, crop, land, open space, or you could put silver PV on it and then the utility well, that's footprint on the ground. So that's pretty much taking up that land.

237 "Mark Jacobson" (1023545600)
00:33:59.264 --> 00:34:08.174
You can't use it for much else, except well, now there's you can put solar panels on agricultural land and if you raise it above the ground, it turns out that.

238 "Mark Jacobson" (1023545600)
00:34:08.349 --> 00:34:21.634

It's actually more efficient for the solar, because it doesn't get it. The panels don't get as hot when it's like, if you put it, like, 6 meters above the ground, then the panel temperature is cooler. So they're more efficient. Plus you can grow crops underneath it.

239 "Mark Jacobson" (1023545600)
00:34:21.754 --> 00:34:28.264
So, you can use that land for multiple purposes. So, the PV here, even though I have point 17% of world land for PV. for pv

240 "Mark Jacobson" (1023545600)
00:34:28.349 --> 00:34:29.639
Csp.

241 "Mark Jacobson" (1023545600)
00:34:30.294 --> 00:34:43.014
Part of that PV you can actually use for multiple purposes. You can put it on the wind land you can grow crops under the PV, or you can put some of that PV on reservoirs and and lakes and even over the ocean.

242 "Mark Jacobson" (1023545600)
00:34:43.104 --> 00:34:49.554
So, it can be off shore, so that could be reduced as well. But in any case, the total for the world is about point 5. 3% of. of

243 "Mark Jacobson" (1023545600)
00:34:49.664 --> 00:35:00.644
Land for the U. S. is about point 84% for the the Northeast U. S. it's about 1.15 in comparison the fossil fuel industry occupies 1.3% of us land area right now.

244 "Mark Jacobson" (1023545600)
00:35:00.644 --> 00:35:09.524
So we're talking that's for the you know, there are 1.3Million active oil and gas wells. There 3.2. one point three million active oil and gas wells there three point two

245 "Mark Jacobson" (1023545600)
00:35:09.639 --> 00:35:18.394
Abandoned oil and gas wells. There are millions of miles of oil and gas pipelines. There are coal mines or refineries their storage facilities.

246 "Mark Jacobson" (1023545600)
00:35:18.544 --> 00:35:29.134
There are hundreds of thousands of gas stations, these, all these facilities and infrastructure occupied about 1.3% of U. S. land. So we think we're going to take less land to transition. land to transition

247 "Mark Jacobson" (1023545600)
00:35:29.519 --> 00:35:34.049
To win water, solar, then currently occupied by fossils.

248 "Mark Jacobson" (1023545600)
00:35:35.579 --> 00:35:45.149
All right, so, let's I'm looking at well, can we keep the grid stable? So we've done great stability analysis for not only the entire world, but also throughout the U. S.

249 "Mark Jacobson" (1023545600)
00:35:45.149 --> 00:35:50.939
And we did the Northeast U. S. but I'm just showing you the results for California here. Uh, so we'd.

250 "Mark Jacobson" (1023545600)
00:35:50.939 --> 00:36:05.304
We're comparing so I, I do computer modeling and I've built a climate and whether an air pollution model over the last 30 years, and on the global scale, but also it's very regional as well. So, people to predict the winds and solar radiation fields.

251 "Mark Jacobson" (1023545600)
00:36:05.939 --> 00:36:09.779
Had a very high resolution in both time and space.

252 "Mark Jacobson" (1023545600)
00:36:09.779 --> 00:36:17.579
So, I use those inputs of win predictions and solar predictions to generate wind and solar fields.

253 "Mark Jacobson" (1023545600)
00:36:17.579 --> 00:36:26.969
That, and for future years, and this is for 2015 2051 throughout the world. And so this shows a comparison of modeled.

254 "Mark Jacobson" (1023545600)
00:36:26.969 --> 00:36:37.679
Uh, when did solar output, and also Hydro output and geothermal entitled wave out, but compared with demand for energy, we have profiles of demand for energy.

255 "Mark Jacobson" (1023545600)
00:36:37.679 --> 00:36:49.379
And we find that we can match supply, wind, water, solar supply with demand plus changes and storage and accounting for losses of energy. Plus wasted energy.

256 "Mark Jacobson" (1023545600)
00:36:49.379 --> 00:37:04.044
Uh, every 30 seconds for 2 years in California, but also the Northeast and throughout the U. S. and throughout the world there's not a single place in the world. That you have not been able to match demand or supply continuously. We just when water, solar and storage. But then you might ask well, at what cost.

257 "Mark Jacobson" (1023545600)
00:37:04.679 --> 00:37:11.909
Because obviously you can do it didn't do anything and it's some cost and so it could be astronomical. Well, so here's the capital cost.

258 "Mark Jacobson" (1023545600)
00:37:11.909 --> 00:37:20.669
Of such a transition worldwide. It's about 62Trillion dollars U. S. about 9Trillion dollars. China's 13. Connecticut is about 81,000,000,000.

259 "Mark Jacobson" (1023545600)
00:37:20.669 --> 00:37:24.419
To transition entirely to win water solar for all purposes.

260 "Mark Jacobson" (1023545600)
00:37:24.684 --> 00:37:38.364
This is what I call the capital cost of the green New deal for each of these regions are s States and this would eliminate global warming eliminate. Well, eliminate the emissions associated with global warming, eliminate air, pollution, deaths worldwide.

261 "Mark Jacobson" (1023545600)
00:37:38.514 --> 00:37:44.334
It would eliminate energy and security. So this is the capital costs needed to solve all 3 of these problems completely world.

262 "Mark Jacobson" (1023545600)
00:37:44.419 --> 00:37:46.559
What, and.

263 "Mark Jacobson" (1023545600)
00:37:46.559 --> 00:37:53.939
Uh, and by the way, I'll point out, so Tesla just announced their world master plan.

264 "Mark Jacobson" (1023545600)
00:37:53.939 --> 00:38:03.899
Which is basically follow is really closely our plans and in fact, it's, I'd say, 97% of our plan, the only different. So they want to go to.

265 "Mark Jacobson" (1023545600)
00:38:03.899 --> 00:38:14.940
Electrify everything worldwide for all sectors, industry, transportation buildings uh, and the electricity sector would all be from wind water solar as well.

266 "Mark Jacobson" (1023545600)
00:38:14.940 --> 00:38:21.240
Um, their only difference in their the Tesla master master plan, which was released last week.

267 "Mark Jacobson" (1023545600)
00:38:21.240 --> 00:38:29.160
Was that there, you know, for a long distance, heavy transport, like long distance aircraft, we're proposing using hundreds and fuel cells.

268 "Mark Jacobson" (1023545600)
00:38:29.160 --> 00:38:36.750
And they're saying, well, let's use some electro fuels for that and I disagree with that, but it's still a minor difference. But.

269 "Mark Jacobson" (1023545600)
00:38:36.985 --> 00:38:44.425
You know, they say that they're the manufacturing, because they looked in detail at the cost of manufacturing, different technologies and they're not looking at all the energy.

270 "Mark Jacobson" (1023545600)
00:38:44.425 --> 00:38:56.605
Like, we're like, I mean, sorry, they're looking at all the energy, but they're not looking at their when they look at their costs, they're not looking at the total energy costs for the transmission distribution and, and, uh, and all the stores and everything else.

271 "Mark Jacobson" (1023545600)
00:38:56.750 --> 00:39:02.490
They're looking at a percentage of costs near estimate about 14Trillion dollars for their cost and this is.

272 "Mark Jacobson" (1023545600)
00:39:02.490 --> 00:39:08.040
So, but they're looking at something different, but my point is there actually also.

273 "Mark Jacobson" (1023545600)
00:39:08.040 --> 00:39:16.680
Scientifically there, there are around 20 other groups that look at 100% renewable energy systems have been over 700 papers.

274 "Mark Jacobson" (1023545600)
00:39:16.680 --> 00:39:25.825
And all every single 1 of the papers that it has ever been done, finds that it's feasible to go to 100 renewables. So we're not the only ones looking at this now.

275 "Mark Jacobson" (1023545600)
00:39:25.825 --> 00:39:35.155
But it's nice actually to see Tesla who's actually building, you know, they're building a lot of, uh, electrification equipment and machines. Um, there's also a board with this as well. well

276 "Mark Jacobson" (1023545600)
00:39:36.115 --> 00:39:47.515
But Here's kind of how the cost comparison with business as usual shakes out. When you look at this is really, really what you want to look at what's the annual cost of of these different systems?

277 "Mark Jacobson" (1023545600)
00:39:47.815 --> 00:39:55.405
So, right now the world spends about 11Trillion dollars per year on energy, and that's expected to go up by 20. twenty

278 "Mark Jacobson" (1023545600)
00:39:55.460 --> 00:40:09.885
50 to about 18Trillion dollars per year health costs about are about 30Trillion today and that's expected to be similar in 2050 about 34Trillion climate costs. We expect to be about 32Trillion. So total social cost of 83Trillion dollars per year in 2050, due to fossil fuels and biofilms.

279 "Mark Jacobson" (1023545600)
00:40:09.885 --> 00:40:13.785
dollars per year in two thousand and fifty due to fossil fuels and biofilms

280 "Mark Jacobson" (1023545600)
00:40:14.460 --> 00:40:17.610
If we go to win water solar, we eliminate.

281 "Mark Jacobson" (1023545600)
00:40:17.610 --> 00:40:21.900
Health costs associated with energy, we eliminate climate costs associated with energy.

282 "Mark Jacobson" (1023545600)
00:40:21.900 --> 00:40:28.560
And our energy requirements go down 56%, due to all those efficiency improvements I told you about earlier.

283 "Mark Jacobson" (1023545600)
00:40:29.035 --> 00:40:42.085
And the cost per unit energy goes down another 15%. So we have a 63% reduction in the energy cost from 17.8 to 6.6Trillion per year and a 92% reduction in the social cost from 83.2 to 6.6Trillion dollars per year. This should be such a no brainer, though. Because of this significant cost benefit.

284 "Mark Jacobson" (1023545600)
00:40:42.085 --> 00:40:48.505
per year this should be such a no brainer though because of this significant cost benefit

285 "Mark Jacobson" (1023545600)
00:40:48.560 --> 00:40:50.700
And eliminating health climate in it.

286 "Mark Jacobson" (1023545600)
00:40:50.700 --> 00:40:58.080
And those costs, plus the energy requirements, um, this is what makes us such an, a, um, a worthwhile plan.

287 "Mark Jacobson" (1023545600)
00:40:58.080 --> 00:41:12.570
Yes, let me jump into the last section, which is policies. So our 1st plan for transitioning came out in 4,009, it was a world plan, not looking at individual countries, which is looking at the world as a whole and.

288 "Mark Jacobson" (1023545600)
00:41:12.570 --> 00:41:21.750
We said, yes, we looked at the resources, the water solar resources. We looked at the materials required, and we looked at land use.

289 "Mark Jacobson" (1023545600)
00:41:21.750 --> 00:41:32.185
And some other issues, and we concluded that, technically, and economically possible to transition by 2030, but for social political reasons, a more likely transition would be about 2050 with maybe 80% by 2030 little.

290 "Mark Jacobson" (1023545600)
00:41:32.185 --> 00:41:41.665
Did we know that this would be the scientific basis for what's called the green New deal, which is a plan in the US to transition the U. S. a plan in the us to transition the u s

291 "Mark Jacobson" (1023545600)

00:41:41.750 --> 00:41:44.220
A 100% renewables by 2030.

292 "Mark Jacobson" (1023545600)
00:41:44.220 --> 00:41:51.300
Um, yeah, at the time we were left up pretty much for this plan or if people thought it was pie in the sky.

293 "Mark Jacobson" (1023545600)
00:41:51.300 --> 00:41:57.300
And it just would never happened and it maybe it's me not still happen. But, uh.

294 "Mark Jacobson" (1023545600)
00:41:57.300 --> 00:42:08.700
There was people did not take it seriously and also, at the time utilities were claiming that, oh, we can't even get more than 20% of renewables on the grid without the grid going unstable.

295 "Mark Jacobson" (1023545600)
00:42:08.700 --> 00:42:20.310
But, actually, it wasn't, it was back around 2017 things started to change, because not only were more policies being put in place to transitions.

296 "Mark Jacobson" (1023545600)
00:42:20.310 --> 00:42:34.165
Countries and states to 100 renewables, but, you know, academics, we're starting to look at this in more detail and also utilities and and what people are saying, we can't do more than 20%, just renewables on the grid back in 22,009.

297 "Mark Jacobson" (1023545600)
00:42:34.165 --> 00:42:40.195
but by 2017 years, they changed this to about 80%. They thought, well, we can keep the. about eighty percent they thought well we can keep the

298 "Mark Jacobson" (1023545600)
00:42:41.145 --> 00:42:51.315
We might be able to keep the grid stable with 80% renewables, but we can never get to 100% but that, you know, but any number 20% or 80% is fiction. I mean, there's no reason we can't go to 100% renewables and keep the grid stable.

299 "Mark Jacobson" (1023545600)
00:42:51.315 --> 00:43:00.285
That's those are just arbitrary numbers and so, actually, since then, you know, then a few years later, it went from 80% is the limit to 90%. from eighty percent is the limit to ninety percent

300 "Mark Jacobson" (1023545600)
00:43:00.310 --> 00:43:06.210
And now, even enrail agrees that we can go to 100% renewable energy on the grid.

301 "Mark Jacobson" (1023545600)
00:43:06.865 --> 00:43:19.465
And in fact, there are 62 countries now that have laws or or or commitments of other kinds to go to 100% renewables in the electric power sector. Uh, only 1, Denmark has laws to go to 100% renewables in all energy sectors.

302 "Mark Jacobson" (1023545600)
00:43:19.465 --> 00:43:26.065
So, this is becoming mainstream this idea of going to 100% renewables. of going to one hundred percent renewables

303 "Mark Jacobson" (1023545600)
00:43:26.210 --> 00:43:31.320
For 400 international companies, in fact, committed to 100% renewables.

304 "Mark Jacobson" (1023545600)
00:43:31.320 --> 00:43:35.490
Including 8 of the 10 biggest companies in the world, and which are the ones in blue.

305 "Mark Jacobson" (1023545600)
00:43:35.490 --> 00:43:48.060
And these companies are building, wind farms and solar farms and battery storage facilities, and electric. They're buying electric vehicle fleets. And so this is they're really making a difference.

306 "Mark Jacobson" (1023545600)
00:43:48.325 --> 00:44:02.935
And, uh, there are also 19 States and territories that have laws or executive orders to go to 100% renewables for different years. And those are listed here, Connecticut is 1 by 2040. and these are well, I should say these are 100% renewables.

307 "Mark Jacobson" (1023545600)
00:44:02.935 --> 00:44:04.975
say these are one hundred percent renewables

308 "Mark Jacobson" (1023545600)
00:44:05.695 --> 00:44:19.825
Or effectively, 100% renewable. So, when I say effectively, that means that some of them allow nuclear power to be included, but they're also allow 100% renewables if there's no nuclear power. But there. So there are sometimes some of them call themselves like, uh.

309 "Mark Jacobson" (1023545600)
00:44:19.825 --> 00:44:21.055
call themselves like uh

310 "Mark Jacobson" (1023545600)
00:44:21.870 --> 00:44:30.030
0, net energy, you know, summary specifically many most of them are specifically 100% renewables, but some of them are like 0, net energy or.

311 "Mark Jacobson" (1023545600)
00:44:30.030 --> 00:44:37.710
Um, use some other terminology, but allow 100 renewables and that's the most likely scenario because there's no new nuclear being built.

312 "Mark Jacobson" (1023545600)
00:44:37.710 --> 00:44:46.440
Anywhere accepted Georgia and even that is gonna be the last 1. there's nothing else being constructed even aside from the plant in Georgia.

313 "Mark Jacobson" (1023545600)
00:44:46.440 --> 00:44:56.250
And so all these nuclear plants that exist in the U. S. are going to retire. And so when they retire, they're not going to be replaced by nuclear because it takes too long. It takes.

314 "Mark Jacobson" (1023545600)
00:44:56.250 --> 00:45:04.410
17 to 20 years to build it. So so anyway, these are all 100% renewable plans effectively. There are 180 U. S cities.

315 "Mark Jacobson" (1023545600)
00:45:04.410 --> 00:45:10.260
And counties that have committed to 100% renewables as well, they're 400 worldwide.

316 "Mark Jacobson" (1023545600)
00:45:10.260 --> 00:45:14.430
There are actually 16 countries that are at 100% renewables.

317 "Mark Jacobson" (1023545600)
00:45:14.430 --> 00:45:20.100
In terms of either generation of consumption or near add or near. So the 9 on the left.

318 "Mark Jacobson" (1023545600)
00:45:20.100 --> 00:45:28.530

Are all at 100% renewable generation, but all of them produce their biggest source of electricity's hydropower.

319 "Mark Jacobson" (1023545600)
00:45:28.530 --> 00:45:33.270
And then they also list their 2nd source, which either geothermal or wind or solar.

320 "Mark Jacobson" (1023545600)
00:45:33.270 --> 00:45:44.490
There are 3 countries, Kenya to Namibia that are around 91% generation from, from water solar and then the 4 on the right these are looking at their.

321 "Mark Jacobson" (1023545600)
00:45:44.490 --> 00:45:52.980
Of their consumed energy so, South Dakota, for example, 126% of the electricity consumed in South Dakota is produced by wind.

322 "Mark Jacobson" (1023545600)
00:45:52.980 --> 00:46:05.605
77% wind and the rest hydro and it also, South Dakota also produces fossil fuels all the. So the T, it produces about 150% of its electricity consumed and the, the remaining 50% is exported to different states.

323 "Mark Jacobson" (1023545600)
00:46:05.605 --> 00:46:12.895
But the point is, if you just look at the consumption, you can match all that consumption. consumption you can match all that consumption

324 "Mark Jacobson" (1023545600)
00:46:12.980 --> 00:46:23.730
When water solar in South Dakota, Washington state, it's about 98% Scotland is about 91%, montana's about 91% of its consumption is from wind water solar.

325 "Mark Jacobson" (1023545600)
00:46:23.730 --> 00:46:37.585
And then, okay, so just to summarize so I'm getting at the end here. Uh, well, I didn't talk about jobs, but we did find that we could we'd create worldwide about 28Million, more long term, full time jobs than lost in the U. S. it's about 3 to 4Million in Connecticut also.

326 "Mark Jacobson" (1023545600)
00:46:37.915 --> 00:46:42.055
Good on the order of 50,000 new jobs. fifty thousand new jobs

327 "Mark Jacobson" (1023545600)

00:46:42.480 --> 00:46:45.630
More more jobs produced and lost.

328 "Mark Jacobson" (1023545600)
00:46:45.630 --> 00:46:55.740
Require point 53% of world land for footprint and spacing. We'd reduced 7Million air pollution desk per year. We'd slow the reverse global warming.

329 "Mark Jacobson" (1023545600)
00:46:55.740 --> 00:47:02.820
I think we can keep the grid stable throughout the world with a 100% and absolute energy costs are 63% lower.

330 "Mark Jacobson" (1023545600)
00:47:02.820 --> 00:47:07.830
And they search for costs about 92% lower and with fossil fuels.

331 "Mark Jacobson" (1023545600)
00:47:07.830 --> 00:47:12.060
And finally just some more information.

332 "Mark Jacobson" (1023545600)
00:47:12.060 --> 00:47:15.090
And I just finished a book, uh, that was published, uh.

333 "Mark Jacobson" (1023545600)
00:47:15.090 --> 00:47:27.870
Well, no miracles needed is basically summarizing what I talked about and why we don't need miracle technologies like carbon capture direct aircraft, capture blue hydrogen's, electro fuels, et cetera.

334 "Mark Jacobson" (1023545600)
00:47:27.870 --> 00:47:37.680
Um, and then there are individual plans for states and countries are available at the 2nd website. Um, there's no online course I teach on, um.

335 "Mark Jacobson" (1023545600)
00:47:37.680 --> 00:47:40.980
Transitioning to renewables and they're.

336 "Mark Jacobson" (1023545600)
00:47:40.980 --> 00:47:55.615

Submit an infographic map that has that you can go to and click on a state or country or a city, and we'll have an energy plan for the location as well. So, with that, I'm happy to answer any questions you have. Thank you very much for listening.

337 "Marina Astitha (she,her)" (2769029632)
00:47:57.450 --> 00:48:05.040
Thank you so much mark.