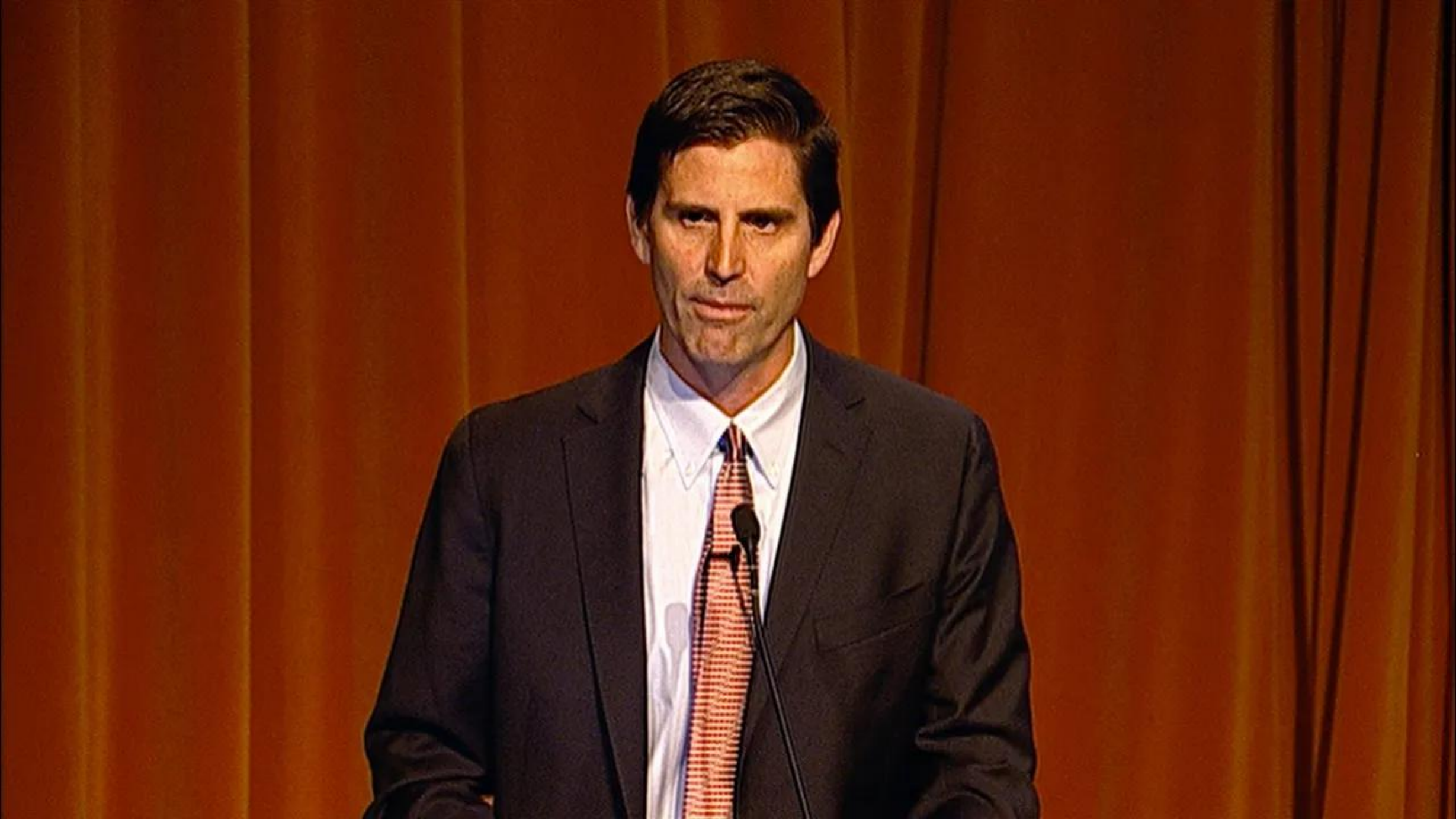

1
00:00:01,000 --> 00:00:07,000
[music playing]

2
00:00:17,000 --> 00:00:19,166
- SO WELCOME TO THE 75th
ANNIVERSARY

3
00:00:19,166 --> 00:00:21,000
OF NASA AMES RESEARCH

4
00:00:21,000 --> 00:00:24,433
AND THE DIRECTOR'S COLLOQUIUM
SUMMER SERIES.

5
00:00:24,433 --> 00:00:29,433
OUR SPECIES IS A SPECIALIST
EVOLVED TO USE OUR ENVIRONMENT

6
00:00:29,433 --> 00:00:34,000
IN NOVEL WAYS IN ORDER TO EXPAND
OUR CAPABILITY TO SURVIVE

7
00:00:34,000 --> 00:00:37,000
NEW ENVIRONMENTS.

8
00:00:37,000 --> 00:00:41,066
OUR SPECIES ALSO OWES
ITS SURVIVAL TO THE ABILITY

9
00:00:41,066 --> 00:00:45,466
TO PREDICT DANGERS
AND TO COUNTER THEM.

10
00:00:45,466 --> 00:00:50,100
OUR HOME PLANET, AND CURRENTLY
OUR ONLY HOME PLANET,

11
00:00:50,100 --> 00:00:53,666
EARTH, IS CHANGING IN A WAY

12
00:00:53,666 --> 00:00:58,633
THAT POSES A POTENTIAL DANGER
TO OUR LONG-TERM SURVIVAL.

13
00:00:58,633 --> 00:01:02,633
WHETHER IT'S DUE TO NATURAL,
MANMADE,

14
00:01:02,633 --> 00:01:05,966
OR A COMBINATION OF CAUSES,

15
00:01:05,966 --> 00:01:08,400
WE NEED TO FIND SOLUTIONS.

16
00:01:08,400 --> 00:01:11,966
TODAY'S PRESENTATION
IS ENTITLED,

17
00:01:11,966 --> 00:01:16,066
"ROADMAPS FOR TRANSITIONING
ALL 50 U.S. STATES

18
00:01:16,066 --> 00:01:19,766
TO WIND, WATER,
AND SOLAR POWER."

19
00:01:19,766 --> 00:01:23,733
IT WILL BE PRESENTED
BY DR. MARK JACOBSON.

20
00:01:23,733 --> 00:01:26,133
DR. JACOBSON IS A DIRECTOR

21
00:01:26,133 --> 00:01:28,900
OF THE ATMOSPHERE
AND ENERGY PROGRAM,

22
00:01:28,900 --> 00:01:31,866

AND PROFESSOR OF CIVIL
AND ENVIRONMENTAL ENGINEERING

23
00:01:31,866 --> 00:01:34,400
AT STANFORD UNIVERSITY.

24
00:01:34,400 --> 00:01:36,700
HE IS ALSO A SENIOR FELLOW

25
00:01:36,700 --> 00:01:39,033
OF THE WOODS INSTITUTE
FOR ENVIRONMENT,

26
00:01:39,033 --> 00:01:42,300
AND OF THE PRECOURT INSTITUTE
FOR ENERGY.

27
00:01:42,300 --> 00:01:46,566
DR. JACOBSON RECEIVED A B.S.
IN CIVIL ENGINEERING,

28
00:01:46,566 --> 00:01:49,133
AN A.B. IN ECONOMICS,

29
00:01:49,133 --> 00:01:52,733
AND AN M.S. IN ENVIRONMENTAL
ENGINEERING FROM STANFORD.

30
00:01:52,733 --> 00:01:56,233
HE ALSO RECEIVED
AN M.S. AND PhD

31
00:01:56,233 --> 00:01:59,900
IN ATMOSPHERIC SCIENCES
FROM UCLA.

32
00:01:59,900 --> 00:02:03,533
DR. JACOBSON IS AN AUTHOR
OF TWO TEXTBOOKS,

33
00:02:03,533 --> 00:02:07,300
AND HAS OVER 140 PEER-REVIEWED
ARTICLES.

34
00:02:07,300 --> 00:02:10,900
FOR HIS WORK HE HAS RECEIVED
NUMEROUS AWARDS,

35
00:02:10,900 --> 00:02:15,666
INCLUDING THE 2005 AMERICAN
METEOROLOGICAL SOCIETY

36
00:02:15,666 --> 00:02:18,500
HENRY G. HOUGHTON AWARD,

37
00:02:18,500 --> 00:02:23,500
AND THE 2013 AMERICAN
GEOPHYSICAL UNION ASCENT AWARD,

38
00:02:23,500 --> 00:02:26,566
AND THE GREEN GLOBAL POLICY
DESIGN AWARD.

39
00:02:26,566 --> 00:02:30,433
PLEASE JOIN ME IN WELCOMING
DR. MARK JACOBSON.

40
00:02:30,433 --> 00:02:32,766
[applause]

41
00:02:38,333 --> 00:02:42,400
- THANK YOU VERY MUCH, JACOB,
FOR THAT VERY KIND INTRODUCTION.

42
00:02:42,400 --> 00:02:45,766
AND SO I WANT TO TALK TODAY
ABOUT ENERGY PLANS

43
00:02:45,766 --> 00:02:49,266

THAT WE'VE BEEN DEVELOPING
AND HOPE TO IMPLEMENT

44
00:02:49,266 --> 00:02:51,233
ON CHANGING THE ENERGY
INFRASTRUCTURE

45
00:02:51,233 --> 00:02:54,533
OF THE UNITED STATES AND,
ULTIMATELY, THE WHOLE WORLD.

46
00:02:54,533 --> 00:02:58,700
AND I'LL START WITH THE--
YOU KNOW, WHAT'S THE PROBLEM?

47
00:02:58,700 --> 00:03:00,833
IT'S A MOTIVATION. SO I'LL LOOK
AT THE PROBLEM FIRST,

48
00:03:00,833 --> 00:03:02,866
AND THEN GET INTO
THE SOLUTIONS.

49
00:03:02,866 --> 00:03:04,366
AND I PROBABLY DON'T HAVE
TO CONVINCE YOU

50
00:03:04,366 --> 00:03:06,700
THAT THERE ARE PROBLEMS
THAT SOME AUDIENCES--

51
00:03:06,700 --> 00:03:08,800
YOU'D SOMETIMES
HAVE TO CONVINCE THEM.

52
00:03:08,800 --> 00:03:12,100
BUT WE LOOK AT IT
FROM AN AIR POLLUTION,

53
00:03:12,100 --> 00:03:15,366

A GLOBAL WARMING, AND ENERGY
SECURITY POINT OF VIEW.

54
00:03:15,366 --> 00:03:17,033
AND IN THE UNITED STATES,

55
00:03:17,033 --> 00:03:19,833
ABOUT 63,000 PEOPLE DIE
EVERY YEAR PREMATURELY

56
00:03:19,833 --> 00:03:21,300
FROM AIR POLLUTION,

57
00:03:21,300 --> 00:03:25,366
AND HUNDREDS OF THOUSANDS MORE
BECOME ILL DUE TO AIR POLLUTION.

58
00:03:25,366 --> 00:03:30,266
AND THIS COSTS THE U.S.
ABOUT 3.2% OF THE G.D.P.,

59
00:03:30,266 --> 00:03:33,266
UH, LOOKING AT--BASED ON
STATISTICAL COST OF LIFE

60
00:03:33,266 --> 00:03:35,000
AND ILLNESS.

61
00:03:35,000 --> 00:03:37,533
AND WORLDWIDE, THERE ARE ABOUT
3 TO 7 MILLION PEOPLE

62
00:03:37,533 --> 00:03:39,333
DIE PREMATURELY EACH YEAR.

63
00:03:39,333 --> 00:03:41,366
AND ALMOST ALL
THIS AIR POLLUTION

64

00:03:41,366 --> 00:03:45,233
IS DUE TO FOSSIL FUEL EMISSIONS
AND BIOFUEL EMISSIONS.

65
00:03:45,233 --> 00:03:49,066
AND GLOBAL WARMING, OF COURSE,
IS A GROWING PROBLEM

66
00:03:49,066 --> 00:03:50,966
AND ALREADY CAUSING
SIGNIFICANT DAMAGE.

67
00:03:50,966 --> 00:03:54,366
AND IN TERMS OF MONETARY COSTS,
IT'S--ONE ESTIMATE,

68
00:03:54,366 --> 00:03:56,033
AND THERE ARE A LOT OF DIFFERENT
ESTIMATES OUT THERE,

69
00:03:56,033 --> 00:04:00,533
IS BY 2050
ABOUT $730 BILLION PER YEAR

70
00:04:00,533 --> 00:04:02,833
FROM JUST U.S. EMISSIONS ALONE.

71
00:04:02,833 --> 00:04:06,500
AND THESE ARE WORLDWIDE COSTS
OF $730 BILLION.

72
00:04:06,500 --> 00:04:08,500
OTHER PROBLEMS
ARE THE FINITE--

73
00:04:08,500 --> 00:04:10,433
FOSSIL FUELS
ARE FINITE RESOURCES,

74
00:04:10,433 --> 00:04:14,000

AND THEIR COSTS ARE GOING UP
BECAUSE THE FUEL--

75
00:04:14,000 --> 00:04:17,266
THERE'S A FUEL COST
THAT KEEPS GROWING.

76
00:04:17,266 --> 00:04:20,033
IN COMPARISON,
RENEWABLE ENERGY

77
00:04:20,033 --> 00:04:22,533
SUCH AS WIND,
AND SOLAR POWER IN PARTICULAR,

78
00:04:22,533 --> 00:04:26,100
OR GEOTHERMAL, HYDROELECTRIC,
THE FUEL COST IS ZERO.

79
00:04:26,100 --> 00:04:28,666
SO YOU CAN EXPECT YOU MIGHT BE
ABLE TO STABILIZE ENERGY PRICES

80
00:04:28,666 --> 00:04:30,933
BY GOING TO THOSE FUELS.

81
00:04:30,933 --> 00:04:33,400
JOBS IS ANOTHER ISSUE.

82
00:04:33,400 --> 00:04:35,533
AND AS WE'LL SEE,

83
00:04:35,533 --> 00:04:37,133
WITH THE FOSSIL FUEL INDUSTRY

84
00:04:37,133 --> 00:04:39,200
WE'RE ACTUALLY CAUSING
JOB STAGNATION

85

00:04:39,200 --> 00:04:42,933
BECAUSE THERE'S ACTUALLY FEWER
JOBS ASSOCIATED WITH THAT

86
00:04:42,933 --> 00:04:45,966
THAN IN BURGEONING
WIND/WATER/SOLAR INDUSTRY.

87
00:04:45,966 --> 00:04:47,500
SO I'LL GIVE YOU NUMBERS
ON THAT.

88
00:04:47,500 --> 00:04:49,733
SO THESE ARE ALL
DRASTIC PROBLEMS,

89
00:04:49,733 --> 00:04:53,133
BECAUSE YOU CAN IMAGINE
IF PRICES GO UP OVER TIME

90
00:04:53,133 --> 00:04:56,500
OF FUELS,
THEN THAT WOULD EVENTUALLY,

91
00:04:56,500 --> 00:04:59,366
AS IF THE PRICES
GET BEYOND A CERTAIN LEVEL,

92
00:04:59,366 --> 00:05:04,366
THEN YOU CAN GET NOT ONLY
ECONOMIC AND SOCIAL INSTABILITY,

93
00:05:04,366 --> 00:05:07,266
BUT ALSO POLITICAL INSTABILITY
AND POSSIBLY CIVIL WAR.

94
00:05:07,266 --> 00:05:09,233
SO THESE ARE ALL
DRASTIC PROBLEMS

95

00:05:09,233 --> 00:05:11,900
THAT REQUIRE
DRASTIC SOLUTIONS.

96
00:05:11,900 --> 00:05:14,433
AND THE SOLUTIONS THAT I'M GOING
TO TALK ABOUT

97
00:05:14,433 --> 00:05:16,400
ARE WIND/WATER/SOLAR
SOLUTIONS.

98
00:05:16,400 --> 00:05:19,600
THESE WILL ALL ELIMINATE
AIR POLLUTION DEATH,

99
00:05:19,600 --> 00:05:22,333
ELIMINATE ALMOST ALL
GLOBAL WARMING,

100
00:05:22,333 --> 00:05:27,200
AND PROVIDE JOB AND ENERGY
SECURITY AND PRICE SECURITY.

101
00:05:27,200 --> 00:05:30,133
SO LET'S JUST LOOK A LITTLE BIT
MORE AT THE PROBLEMS.

102
00:05:30,133 --> 00:05:32,233
IN THE UNITED STATES,
WE LOOK AROUND AND WE SEE,

103
00:05:32,233 --> 00:05:34,500
WELL, IT DOESN'T LOOK
THAT DIRTY.

104
00:05:34,500 --> 00:05:36,566
YOU KNOW, HOW DO PEOPLE DIE
FROM AIR POLLUTION?

105

00:05:36,566 --> 00:05:39,000
WELL, YOU CAN ACTUALLY
JUST LOOK AT ALL--

106
00:05:39,000 --> 00:05:40,733
TAKE MEASUREMENTS
OF THE POLLUTION LEVELS

107
00:05:40,733 --> 00:05:43,466
AT ALL THE MONITORING STATIONS
IN THE U.S.

108
00:05:43,466 --> 00:05:48,100
AND LOOK AT EPIDEMIOLOGICAL DATA
THAT HAS BEEN GATHERED

109
00:05:48,100 --> 00:05:51,166
FOR THE LAST
40 YEARS OR SO.

110
00:05:51,166 --> 00:05:54,266
AND APPLY DOSE-RESPONSE
RELATIONSHIPS,

111
00:05:54,266 --> 00:05:55,833
AND LOOK AT THE POPULATIONS
THAT ARE EXPOSED

112
00:05:55,833 --> 00:05:57,400
TO THE CONCENTRATIONS.

113
00:05:57,400 --> 00:06:00,066
THIS IS WHERE YOU'LL GET
ABOUT 60,000 DEATHS PER YEAR

114
00:06:00,066 --> 00:06:01,566
IN THE U.S.

115
00:06:01,566 --> 00:06:03,166
BUT IN PLACES LIKE CHINA,

116
00:06:03,166 --> 00:06:04,800
THERE ARE ABOUT
A MILLION DEATHS ALONE

117
00:06:04,800 --> 00:06:06,633
PREMATURELY EACH YEAR.

118
00:06:06,633 --> 00:06:09,000
IN BEIJING--THIS IS A PHOTO
OF BEIJING, CHINA.

119
00:06:09,000 --> 00:06:10,366
AND YOU CAN KIND OF SEE--

120
00:06:10,366 --> 00:06:12,333
REALLY SEE AND VISUALIZE
THE POLLUTION.

121
00:06:12,333 --> 00:06:16,033
IT'S LIKE SMOKING TWO TO THREE
PACKS OF CIGARETTES PER DAY.

122
00:06:16,033 --> 00:06:17,933
AND IF YOU THINK
THAT'S UNUSUAL,

123
00:06:17,933 --> 00:06:19,966
IN LOS ANGELES IN THE 1970s,

124
00:06:19,966 --> 00:06:22,666
IT WAS EQUIVALENT TO SMOKING
TWO PACKS OF CIGARETTES A DAY.

125
00:06:22,666 --> 00:06:24,933
AND THESE ARE THE LUNGS
OF A TEENAGE NON-SMOKER

126
00:06:24,933 --> 00:06:26,600

WHO DIED IN A CAR CRASH,

127
00:06:26,600 --> 00:06:29,000
LIVING IN LOS ANGELES
IN THE 1970s.

128
00:06:29,000 --> 00:06:32,566
SO, YOU KNOW, GENERALLY EVEN
TODAY IN THE UNITED STATES,

129
00:06:32,566 --> 00:06:34,166
A PERSON WHO LIVES IN
A BIG CITY

130
00:06:34,166 --> 00:06:38,066
LOSES ABOUT SIX TO EIGHT MONTHS
OF THEIR LIFE PREMATURELY

131
00:06:38,066 --> 00:06:40,666
ON AVERAGE DUE TO PART OF--

132
00:06:40,666 --> 00:06:44,166
MOSTLY PARTICULATE MATTER,
BUT ALSO OZONE AND CARCINOGENS.

133
00:06:44,166 --> 00:06:46,633
SO POLLUTION IS STILL
A MAJOR PROBLEM.

134
00:06:46,633 --> 00:06:49,266
IN TERMS OF CLIMATE,

135
00:06:49,266 --> 00:06:52,933
THIS--THIS GRAPH SHOWS
THE TEMPERATURE CHANGE

136
00:06:52,933 --> 00:06:57,566
IN RECENT YEARS
COMPARED TO 1900.

137
00:06:57,566 --> 00:07:01,633
AND BETWEEN--WELL, COMPARED
TO 1900 TO 1920 AVERAGE.

138
00:07:01,633 --> 00:07:04,366
AND THE DATA AREN'T GREAT,
BUT WHAT IT DOES INDICATE:

139
00:07:04,366 --> 00:07:06,366
ABOUT A 0.9-DEGREE WARMING.

140
00:07:06,366 --> 00:07:11,166
THAT'S 0.9 DEGREES CELSIUS
WARMING OF THE CLIMATE.

141
00:07:11,166 --> 00:07:13,633
AND MOST OF THE WARMING
IS IN THE NORTHERN HEMISPHERE,

142
00:07:13,633 --> 00:07:15,066
AND PARTICULARLY
OVER THE ARCTIC.

143
00:07:15,066 --> 00:07:17,166
SO THE ARCTIC SEA ICE
IS DISAPPEARING RAPIDLY

144
00:07:17,166 --> 00:07:19,333
AS A RESULT OF THESE HIGHER
TEMPERATURES.

145
00:07:19,333 --> 00:07:21,966
AND IF IT MELTS ENTIRELY,

146
00:07:21,966 --> 00:07:24,266
YOU CAN EXPECT
POSITIVE FEEDBACK

147
00:07:24,266 --> 00:07:26,833

AS YOU UNCOVER
THE DARK OCEAN BELOW.

148
00:07:26,833 --> 00:07:29,800
NOW, ONE OF THE PROBLEMS
WITH--

149
00:07:29,800 --> 00:07:32,300
IT'S NOT ONLY CO2 AND OTHER
GREENHOUSE GASES

150
00:07:32,300 --> 00:07:33,833
THAT ARE CAUSING MELTING
OF THE ARCTIC.

151
00:07:33,833 --> 00:07:36,033
IT'S ALSO THINGS
LIKE BLACK CARBON,

152
00:07:36,033 --> 00:07:38,166
WHICH IS A MAIN COMPONENT
OF SOOT,

153
00:07:38,166 --> 00:07:39,800
WHICH IS EMITTED
FROM DIESEL EXHAUST,

154
00:07:39,800 --> 00:07:42,333
JET AIRCRAFT,
KEROSENE BURNING,

155
00:07:42,333 --> 00:07:45,166
AND BIOFUEL
AND BIOMASS BURNING.

156
00:07:45,166 --> 00:07:48,600
AND THE DARKENING OF SNOW
AND SEA ICE

157
00:07:48,600 --> 00:07:50,066

INCREASES ITS MELT RATE.

158
00:07:50,066 --> 00:07:53,400
IN FACT, BLACK CARBON, NOT ONLY
DUE TO ITS DARKENING OF SNOW

159
00:07:53,400 --> 00:07:55,266
BUT ITS IMPACT--
BECAUSE IN THE AIR,

160
00:07:55,266 --> 00:07:58,300
BLACK CARBON IS A MILLION TIMES
MORE POWERFUL PER UNIT MASS

161
00:07:58,300 --> 00:08:01,000
AT WARMING THE AIR
THAN CARBON DIOXIDE,

162
00:08:01,000 --> 00:08:03,766
BUT HAS A MUCH SHORTER
LIFETIME.

163
00:08:03,766 --> 00:08:06,233
BUT IT NOT ONLY
MELTS THE ARCTIC,

164
00:08:06,233 --> 00:08:10,400
IT WARMS THE AIR DIRECTLY,
BUT IT ALSO EVAPORATES CLOUDS.

165
00:08:10,400 --> 00:08:12,766
SO YOU CAN GET, IN REGIONS
OF CHINA, FOR EXAMPLE,

166
00:08:12,766 --> 00:08:14,800
YOU DON'T HAVE
REAL CLOUDS ANYMORE

167
00:08:14,800 --> 00:08:16,333
JUST BECAUSE YOU HAVE SO MUCH

BLACK CARBON

168
00:08:16,333 --> 00:08:17,566
THAT EVAPORATES THE CLOUDS,

169
00:08:17,566 --> 00:08:20,433
CAUSING THEM TO BECOME
MORE HAZY.

170
00:08:20,433 --> 00:08:22,333
AND MORE SOLAR RADIATION
THAT REACHES THE SURFACE,

171
00:08:22,333 --> 00:08:25,433
WARMING THE SURFACE FASTER
IN A POSITIVE FEEDBACK LOOP.

172
00:08:25,433 --> 00:08:28,666
WELL, THIS BLACK CARBON,
I MEAN, ONE OF THE MAIN EMITTERS

173
00:08:28,666 --> 00:08:31,266
OR ONE OF THE GROWING EMITTERS
IS, FOR EXAMPLE,

174
00:08:31,266 --> 00:08:34,933
NATURAL GAS,
BURNING FLARING.

175
00:08:34,933 --> 00:08:37,166
AND SO YOU HAVE ALL THESE FLARES
PUTTING OUT BLACK CARBON,

176
00:08:37,166 --> 00:08:39,333
BUT YOU ALSO HAVE
A LOT OF DIESEL EXHAUST.

177
00:08:39,333 --> 00:08:43,266
SO ENERGY--WE'LL GET INTO KIND
OF THE ENERGY SOLUTIONS

178
00:08:43,266 --> 00:08:45,400
THAT HAVE BEEN PROPOSED
THAT AREN'T SO GREAT.

179
00:08:45,400 --> 00:08:48,466
BUT--SO NATURAL GAS
CAN BE ONE OF THEM.

180
00:08:48,466 --> 00:08:49,933
IN TERMS OF CLIMATE,

181
00:08:49,933 --> 00:08:52,533
GLOBAL TEMPERATURES
ARE RISING FAST.

182
00:08:52,533 --> 00:08:56,500
AS I MENTIONED WHEN WE SAW
THE ANOMALIES ABOUT .9 DEGREES

183
00:08:56,500 --> 00:08:59,433
SINCE THE EARLY 1900s,

184
00:08:59,433 --> 00:09:02,000
THIS JUST SHOWS
AN AVERAGE TREND

185
00:09:02,000 --> 00:09:03,466
INDICATING THE SAME THING,

186
00:09:03,466 --> 00:09:05,666
BUT KIND OF SHOWING HOW,
IN MORE RECENT YEARS,

187
00:09:05,666 --> 00:09:07,266
IN THE LAST 30, 40 YEARS,

188
00:09:07,266 --> 00:09:09,533
THERE'S BEEN AN ACCELERATION

OF WARMING.

189
00:09:09,533 --> 00:09:12,033
IT'S NOT THAT
WE HAVEN'T HAD--

190
00:09:12,033 --> 00:09:13,833
IN THE PAST, PEOPLE WHO DENIED
GLOBAL WARMING

191
00:09:13,833 --> 00:09:16,433
HAVE SAID, "WELL, TEMPERATURES
HAVE BEEN WARMER IN THE PAST."

192
00:09:16,433 --> 00:09:17,733
AND THAT'S TRUE.

193
00:09:17,733 --> 00:09:20,400
100 MILLION YEARS AGO
THE EARTH WAS ICE-FREE.

194
00:09:20,400 --> 00:09:22,133
BUT, OF COURSE,
NOBODY LIVED BACK THEN.

195
00:09:22,133 --> 00:09:26,766
SO IT DIDN'T CAUSE, YOU KNOW,
ALL THE MELTING OF THE ICE

196
00:09:26,766 --> 00:09:29,200
WHICH, TODAY, IF YOU MELTED
ALL THE ICE WORLDWIDE,

197
00:09:29,200 --> 00:09:33,433
YOU'D HAVE 70 METERS MORE
OF SEA LEVEL, HIGHER SEA LEVEL.

198
00:09:33,433 --> 00:09:36,766
AND THAT WOULD COVER 7%
OF THE WORLD'S LAND.

199
00:09:36,766 --> 00:09:38,933
AND MOST PEOPLE LIVE
ALONG THE COAST.

200
00:09:38,933 --> 00:09:41,700
SO THE PROBLEM IS
WE HAVE WARMING

201
00:09:41,700 --> 00:09:44,233
IN THE PRESENCE OF 7 BILLION
PEOPLE ON EARTH.

202
00:09:44,233 --> 00:09:47,733
AND THIS IS
A GREAT PROBLEM,

203
00:09:47,733 --> 00:09:51,300
BECAUSE IT WOULD CAUSE
NOT ONLY LARGE POPULATION SHIFTS

204
00:09:51,300 --> 00:09:54,100
DUE TO COVERING
OF THE COASTLINES,

205
00:09:54,100 --> 00:09:57,033
BUT ALSO LOTS OF HEAT STRESS
AND HEAT STROKE,

206
00:09:57,033 --> 00:09:59,866
CHANGE IN AGRICULTURE,
ACIDIFICATION OF THE OCEANS,

207
00:09:59,866 --> 00:10:01,400
INCREASED AIR POLLUTION,

208
00:10:01,400 --> 00:10:03,800
INCREASED SEVERE STORMINESS,
ET CETERA.

209
00:10:03,800 --> 00:10:06,933
SO ALL THESE PROBLEMS
ASSOCIATED WITH GLOBAL WARMING

210
00:10:06,933 --> 00:10:08,933
HAVE COSTS ASSOCIATED
WITH IT.

211
00:10:08,933 --> 00:10:12,566
NOW IF WE LOOK AT NET OBSERVED
GLOBAL WARMING

212
00:10:12,566 --> 00:10:14,500
WHICH, AS I MENTIONED,
IS ON THE ORDER OF--

213
00:10:14,500 --> 00:10:16,033
WELL, IT'S ON THE ORDER
OF .9 DEGREES,

214
00:10:16,033 --> 00:10:17,833
OR .8, DEPENDING ON WHICH DATA
YOU LOOK AT,

215
00:10:17,833 --> 00:10:21,400
THAT'S THIS RIGHT BAR,
IS A NET OBSERVED WARMING.

216
00:10:21,400 --> 00:10:23,433
THAT'S REALLY A COMBINATION

217
00:10:23,433 --> 00:10:26,033
OF GREENHOUSE GAS WARMING
ON THE LEFT,

218
00:10:26,033 --> 00:10:28,900
WHICH IS OVER
2 DEGREES CELSIUS,

219

00:10:28,900 --> 00:10:31,266
AND FOSSIL FUEL,
BIOFUEL SOOT WARMING,

220
00:10:31,266 --> 00:10:34,166
WHICH IS ON THE ORDER
OF HALF A DEGREE CELSIUS,

221
00:10:34,166 --> 00:10:36,066
AND A LITTLE BIT
OF URBAN HEAT ISLAND EFFECT.

222
00:10:36,066 --> 00:10:40,866
BUT MINUS COOLING
DUE TO AIR POLLUTION PARTICLES

223
00:10:40,866 --> 00:10:44,266
THAT ARE REFLECTIVE,
SUCH AS SULFATES AND NITRATES

224
00:10:44,266 --> 00:10:46,566
AND CERTAIN ORGANIC MATTER,

225
00:10:46,566 --> 00:10:48,800
AND ASSOCIATED WATER
AND AMMONIA.

226
00:10:48,800 --> 00:10:51,300
AND THESE COOLING PARTICLES

227
00:10:51,300 --> 00:10:53,233
OFFSET ABOUT HALF
OF THE GLOBAL WARMING.

228
00:10:53,233 --> 00:10:57,033
SO THAT'S WHY YOU HAVE A SMALLER
NET OBSERVED GLOBAL WARMING

229
00:10:57,033 --> 00:11:00,533
THAN THE GREENHOUSE GASES CAUSE.

230
00:11:00,533 --> 00:11:03,333
BUT YOU CAN IMMEDIATELY SEE
SOME MAJOR PROBLEMS HERE.

231
00:11:03,333 --> 00:11:06,333
IF YOU--IF WE JUST CLEAN UP
AIR POLLUTION PARTICLES,

232
00:11:06,333 --> 00:11:08,833
WE'LL CLEAN OUT THE FOSSIL FUEL
AND BIOFUEL SOOT PARTICLES,

233
00:11:08,833 --> 00:11:10,566
PLUS THE COOLING PARTICLES.

234
00:11:10,566 --> 00:11:13,066
AND ALL OF A SUDDEN
WE WOULD DOUBLE

235
00:11:13,066 --> 00:11:14,733
THE GLOBAL WARMING
THAT'S OCCURRING.

236
00:11:14,733 --> 00:11:16,433
SO THE WARMING
THAT'S IN THE SYSTEM,

237
00:11:16,433 --> 00:11:19,366
HALF THE WARMING IS BEING MASKED
BY POLLUTION

238
00:11:19,366 --> 00:11:22,066
THAT'S CAUSING 3-7 MILLION
DEATHS PER YEAR.

239
00:11:22,066 --> 00:11:23,500
BUT WE WANT TO CLEAN UP
THAT POLLUTION

240
00:11:23,500 --> 00:11:25,033
TO PREVENT THESE DEATHS.

241
00:11:25,033 --> 00:11:28,200
BUT DOING SO WOULD UNCOVER
ALL THIS WARMING IN THE SYSTEM

242
00:11:28,200 --> 00:11:32,200
AND CAUSE RAPID ACCELERATION OF
THE TEMPERATURES OF THE CLIMATE.

243
00:11:32,200 --> 00:11:35,233
NOW, THE OTHER POSSIBLE
SOLUTION--

244
00:11:35,233 --> 00:11:37,266
SO ONE SOLUTION--
WELL, ONE POSSIBLE SOLUTION

245
00:11:37,266 --> 00:11:39,433
IS JUST TO FOCUS
ON THE SOOT PARTICLES,

246
00:11:39,433 --> 00:11:41,566
BECAUSE THE GREENHOUSES GASES
LAST SO LONG

247
00:11:41,566 --> 00:11:43,766
THAT EVEN IF WE ELIMINATE
THEIR EMISSIONS TODAY,

248
00:11:43,766 --> 00:11:45,566
WE WOULDN'T, FOR EXAMPLE,

249
00:11:45,566 --> 00:11:47,666
SLOW THE MELTING
OF THE ARCTIC ICE,

250
00:11:47,666 --> 00:11:50,433

WHICH WILL DISAPPEAR
WITHIN 10 TO 30 YEARS.

251
00:11:50,433 --> 00:11:53,566
BUT IF WE REDUCE THE FOSSIL FUEL
SOOT EMISSIONS,

252
00:11:53,566 --> 00:11:55,733
THEN--WHICH HAVE
A SHORT LIFETIME,

253
00:11:55,733 --> 00:11:59,766
WE CAN ACTUALLY REDUCE
BOTH POLLUTION PARTICLES

254
00:11:59,766 --> 00:12:02,966
THAT CAUSE HEALTH PROBLEMS,
AND WE CAN REDUCE WARMING.

255
00:12:02,966 --> 00:12:04,466
SO THAT'S ONE STRATEGY.

256
00:12:04,466 --> 00:12:08,166
HOWEVER, IT DOESN'T ADDRESS THE
LONG-TERM HEALTH OF THE PLANET

257
00:12:08,166 --> 00:12:10,366
OR MOST OF THE POLLUTION
PARTICLES

258
00:12:10,366 --> 00:12:12,033
THAT CAUSE HEALTH PROBLEMS.

259
00:12:12,033 --> 00:12:14,533
SO THE OTHER SOLUTION IS JUST
TO ELIMINATE ALL THE POLLUTION:

260
00:12:14,533 --> 00:12:15,933
ALL THE GREENHOUSE GASES,

261
00:12:15,933 --> 00:12:17,400
ALL THE FOSSIL FUEL
AND BIOFUEL SOOT,

262
00:12:17,400 --> 00:12:19,366
AND ALL THE COOLING PARTICLES
SIMULTANEOUSLY.

263
00:12:19,366 --> 00:12:21,666
AND THAT'S THE SOLUTION
WE'RE GOING TO FOCUS ON TODAY.

264
00:12:21,666 --> 00:12:23,966
SO HOW DO WE DO THAT?

265
00:12:23,966 --> 00:12:26,466
WELL, WE-- A FEW YEARS AGO
WE DID THIS STUDY LOOKING AT,

266
00:12:26,466 --> 00:12:29,800
WELL, WHAT ARE THE--
POTENTIALLY THE BEST SOLUTIONS

267
00:12:29,800 --> 00:12:32,200
TO GLOBAL WARMING, AIR POLLUTION
AND ENERGY SECURITY?

268
00:12:32,200 --> 00:12:34,566
JUST IN TERMS OF CLEANING UP
THE PROBLEM,

269
00:12:34,566 --> 00:12:36,833
NOT IN TERMS OF THE COSTS.

270
00:12:36,833 --> 00:12:41,833
AND WHAT CAME OUT OF THIS
WAS A RANKING

271
00:12:41,833 --> 00:12:43,400

IN TERMS OF--

272
00:12:43,400 --> 00:12:44,866
WELL, WE LOOKED AT A LOT
OF DIFFERENT IMPACTS

273
00:12:44,866 --> 00:12:47,233
ON THE POLLUTION,
ON GLOBAL CLIMATE,

274
00:12:47,233 --> 00:12:49,300
ON LAND USE,
ON WATER SUPPLY,

275
00:12:49,300 --> 00:12:54,266
ON CATASTROPHIC RISK,
ON RELIABILITY.

276
00:12:54,266 --> 00:12:55,833
AND SOME OTHER FACTORS.

277
00:12:55,833 --> 00:12:58,066
AND THE TECHNOLOGIES
THAT CAME OUT ON TOP

278
00:12:58,066 --> 00:13:00,733
IN TERMS OF ELECTRIC POWER
WERE WIND POWER,

279
00:13:00,733 --> 00:13:04,500
SOLAR PHOTOVOLTAICS
AND CONCENTRATED SOLAR POWER,

280
00:13:04,500 --> 00:13:07,833
GEOTHERMAL POWER,
HYDRO POWER,

281
00:13:07,833 --> 00:13:09,700
HYDROELECTRIC POWER
TO THE EXTENT IT EXISTS,

282
00:13:09,700 --> 00:13:11,833
AND SOME TIDAL AND WAVE POWER.

283
00:13:11,833 --> 00:13:15,100
IN TERMS OF TRANSPORTATION,
IT WAS BATTERY-ELECTRIC VEHICLES

284
00:13:15,100 --> 00:13:17,566
BEING WHERE THE ELECTRICITY
WAS COMING FROM.

285
00:13:17,566 --> 00:13:21,233
THESE, WHAT WE CALL WIND,
WATER AND SOLAR, OR "W.W.S."

286
00:13:21,233 --> 00:13:23,066
ELECTRICITY OPTIONS.

287
00:13:23,066 --> 00:13:24,500
AND HYDROGEN FUEL CELL VEHICLES,

288
00:13:24,500 --> 00:13:28,066
WHERE THE HYDROGEN
ALSO CAME FROM ELECTROLYSIS

289
00:13:28,066 --> 00:13:30,000
BY WHERE THE ELECTRICITY
CAME FROM

290
00:13:30,000 --> 00:13:32,066
IN THE WIND/WATER/SOLAR OPTIONS.

291
00:13:32,066 --> 00:13:34,900
AND FOR AIRCRAFT,
POSSIBLY CRYOGENIC HYDROGEN,

292
00:13:34,900 --> 00:13:36,333
WHICH WAS USED

IN THE SPACE SHUTTLE

293
00:13:36,333 --> 00:13:38,200
TO PROPEL IT INTO SPACE.

294
00:13:38,200 --> 00:13:39,633
ALTHOUGH THAT WOULD
PROBABLY BE

295
00:13:39,633 --> 00:13:41,433
THE LAST THINGS
THAT HAS CHANGED.

296
00:13:41,433 --> 00:13:43,700
FOR HEATING AND COOLING,
WE'D USE THESE ELECTRICITY--

297
00:13:43,700 --> 00:13:46,400
CLEAN ELECTRICITY OPTIONS
TO RUN AIR SOURCE,

298
00:13:46,400 --> 00:13:48,500
GROUND SOURCE AND WATER SOURCE
HEAT PUMPS,

299
00:13:48,500 --> 00:13:50,833
NOT ONLY FOR AIR HEATING
AND AIR CONDITIONING,

300
00:13:50,833 --> 00:13:52,766
BECAUSE THEY CAN BE RUN IN
REVERSE FOR AIR CONDITIONING,

301
00:13:52,766 --> 00:13:55,200
BUT ALSO FOR WATER HEATING.

302
00:13:55,200 --> 00:13:57,700
AND YOU CAN HAVE SOLAR WATER
PRE-HEATERS.

303
00:13:57,700 --> 00:13:59,200
SOME ELECTRIC RESISTANCE
HEATING,

304
00:13:59,200 --> 00:14:02,200
BUT THAT'S LESS EFFICIENT
THAN HEAT PUMPS.

305
00:14:02,200 --> 00:14:05,133
FOR INDUSTRY, WHERE YOU NEED
HIGH-TEMPERATURE PROCESSES,

306
00:14:05,133 --> 00:14:06,633
YOU CAN HAVE THE ELECTRIC
RESISTANCE

307
00:14:06,633 --> 00:14:08,866
OR HYDROGEN COMBUSTION,

308
00:14:08,866 --> 00:14:11,266
WHERE THE HYDROGEN'S PRODUCED
FROM CLEAN ELECTRICITY.

309
00:14:11,266 --> 00:14:13,833
SO THESE ARE ALL
THE OPTIONS

310
00:14:13,833 --> 00:14:15,133
THAT WE ARE GOING
TO BE LOOKING AT,

311
00:14:15,133 --> 00:14:16,966
AND THE NUMBERS
I'LL PRESENT LATER.

312
00:14:16,966 --> 00:14:19,266
BUT YOU MIGHT ASK,
"WELL, WHY DON'T WE INCLUDE

313

00:14:19,266 --> 00:14:23,933
THINGS LIKE BIOFUELS, OR NUCLEAR
POWER, OR NATURAL GAS?"

314
00:14:23,933 --> 00:14:28,266
AND SO WHAT WAS NOT RECOMMENDED
IN THIS ANALYSIS

315
00:14:28,266 --> 00:14:29,566
WAS NUCLEAR POWER,

316
00:14:29,566 --> 00:14:31,766
OR COAL WITH CARBON CAPTURE
AND SEQUESTRATION,

317
00:14:31,766 --> 00:14:34,766
NATURAL GAS OR BIOMASS
FOR ELECTRICITY,

318
00:14:34,766 --> 00:14:36,600
OR FOR VEHICLES,
LIQUID BIOFUELS

319
00:14:36,600 --> 00:14:39,600
SUCH AS CORN OR CELLULOSIC,
OR SUGARCANE ETHANOL,

320
00:14:39,600 --> 00:14:42,666
OR SOY OR ALGAE BIODIESEL,
OR COMPRESSED NATURAL GAS.

321
00:14:42,666 --> 00:14:44,300
AND SO YOU MIGHT ASK, WHY?

322
00:14:44,300 --> 00:14:46,333
WELL, WHY NOT NATURAL GAS?

323
00:14:46,333 --> 00:14:48,666
IN TERMS OF--WELL, FIRST OF ALL,
WE THINK OF EVERYTHING

324
00:14:48,666 --> 00:14:50,700
IN TERMS OF OPPORTUNITY COST.

325
00:14:50,700 --> 00:14:53,433
YOU KNOW, WE'RE NOT GOING TO BE
COMPARING NATURAL GAS AND COAL.

326
00:14:53,433 --> 00:14:55,233
WE COULD DO THAT.
BUT IT'S REALLY--

327
00:14:55,233 --> 00:14:58,066
WE'RE COMPARING NATURAL GAS
VERSUS WIND OR SOLAR.

328
00:14:58,066 --> 00:15:00,966
SO IF WE COMPARE IT TO WIND,
FOR EXAMPLE,

329
00:15:00,966 --> 00:15:05,066
NATURAL GAS PUTS OUT 50 TO 70
TIMES MORE CARBON DIOXIDE,

330
00:15:05,066 --> 00:15:07,966
EQUIVALENT EMISSIONS
AND AIR POLLUTANTS

331
00:15:07,966 --> 00:15:11,566
PER KILOWATT HOUR OF ELECTRICITY
GENERATED THAN WIND DOES.

332
00:15:11,566 --> 00:15:14,800
AND NOT ONLY THAT, IT'S PUTTING
OUT A LOT OF THE BLACK CARBON

333
00:15:14,800 --> 00:15:18,666
FROM FLARING AND METHANE
FROM LEAKAGE THAT HAS--

334
00:15:18,666 --> 00:15:22,133
THE METHANE HAS A RELATIVELY
SHORTER LIFETIME

335
00:15:22,133 --> 00:15:25,400
THAN CARBON DIOXIDE ON THE ORDER
OF EIGHT TO 12 YEARS.

336
00:15:25,400 --> 00:15:28,366
BUT IT'S ONE OF THOSE TWO:
BLACK CARBON AND METHANE ARE--

337
00:15:28,366 --> 00:15:30,666
IF YOU WANT TO CONTROL
THE ARCTIC SEA ICE LOSS,

338
00:15:30,666 --> 00:15:32,300
THOSE ARE REALLY THE ONLY
TWO WAYS YOU CAN CONTROL IT:

339
00:15:32,300 --> 00:15:34,433
ELIMINATING BLACK CARBON,
ELIMINATING METHANE.

340
00:15:34,433 --> 00:15:37,033
BUT NATURAL GAS ACTUALLY
CONTRIBUTES TO BOTH.

341
00:15:37,033 --> 00:15:40,533
DUE TO--IN THE CASE
OF NATURAL GAS,

342
00:15:40,533 --> 00:15:41,733
THERE'S A LEAKAGE RATE.

343
00:15:41,733 --> 00:15:43,100
IF IT'S CONVENTIONAL GAS,

344
00:15:43,100 --> 00:15:46,033

IT'S ON THE ORDER OF 1 TO 2%
OF ALL GASES LEAKED.

345
00:15:46,033 --> 00:15:49,033
BUT IF IT'S NON-CONVENTIONAL,
SUCH AS FROM HYDROFRACKING,

346
00:15:49,033 --> 00:15:51,633
YOU GET LEAKAGE RATES
THAT ARE ANYWHERE UP TO--

347
00:15:51,633 --> 00:15:54,333
THERE ARE SOME STUDIES
THAT GO UP TO 9%,

348
00:15:54,333 --> 00:15:57,866
BUT MORE LIKELY
4-6% LEAKAGE.

349
00:15:57,866 --> 00:16:00,666
NATURAL GAS MINING TRANSPORT
AND USE

350
00:16:00,666 --> 00:16:04,400
CAUSES ABOUT 5,000 PREMATURE
DEATHS PER YEAR IN THE U.S.

351
00:16:04,400 --> 00:16:07,566
AND THAT'S FROM THE COMBUSTION
PRODUCTS OF,

352
00:16:07,566 --> 00:16:08,800
LIKE, FOR EXAMPLE,
WHEN YOU'RE MINING

353
00:16:08,800 --> 00:16:10,600
YOU PUT OUT--YOU USE A LOT
OF FOSSIL FUELS

354
00:16:10,600 --> 00:16:12,933

TO GET THE GAS OUT.

355
00:16:12,933 --> 00:16:15,366
AND SO THERE'S A HEALTH PROBLEM
ASSOCIATED WITH,

356
00:16:15,366 --> 00:16:16,633
THERE'S EMISSIONS.

357
00:16:16,633 --> 00:16:18,366
AND THEN THERE'S WATER SUPPLY
AND LAND USE,

358
00:16:18,366 --> 00:16:20,266
AS YOU CAN SEE
FROM THE PHOTOGRAPH THERE.

359
00:16:20,266 --> 00:16:22,933
I MEAN, THERE ARE TENS
OF THOUSANDS OF WELLS ALONE

360
00:16:22,933 --> 00:16:26,033
FOR HYDROFRACK GAS
IN PENNSYLVANIA.

361
00:16:26,033 --> 00:16:30,366
AND ABOUT 5%
OF ALL FRACKED WELLS,

362
00:16:30,366 --> 00:16:33,900
THE CEMENT CASINGS LEAK
IMMEDIATELY.

363
00:16:33,900 --> 00:16:36,933
AND ABOUT 50% LEAK OVER
THE LIFETIMES OF THE WELL.

364
00:16:36,933 --> 00:16:38,900
SO YOU CAN IMAGINE HAVING TENS
OF THOUSANDS OF WELLS

365
00:16:38,900 --> 00:16:40,366
IN EACH STATE.

366
00:16:40,366 --> 00:16:43,800
LIKE IN PENNSYLVANIA,
AS I MENTIONED, LIKE 70,000.

367
00:16:43,800 --> 00:16:46,233
AND HALF OF THOSE WELLS
ARE GOING TO LEAK

368
00:16:46,233 --> 00:16:48,833
OVER THEIR LIFETIME,
JUST THE CEMENT CASINGS ALONE.

369
00:16:48,833 --> 00:16:51,266
ANY CASE,
THIS IS A PROBLEM,

370
00:16:51,266 --> 00:16:53,000
AND IT'S NOT
A SUSTAINABLE FUTURE.

371
00:16:53,000 --> 00:16:54,866
WHY NOT WHAT'S CALLED
CLEAN COAL,

372
00:16:54,866 --> 00:16:56,866
OR COAL WITH CARBON CAPTURE.

373
00:16:56,866 --> 00:17:01,133
WELL, THAT'S WHERE YOU TAKE
THE CO2 EMISSIONS

374
00:17:01,133 --> 00:17:04,166
FROM THE EXHAUST STREAM
OF THE COAL FIRE POWER PLANT

375

00:17:04,166 --> 00:17:05,500
AND YOU PUMP IT UNDERGROUND.

376
00:17:05,500 --> 00:17:09,466
AND THAT WOULD REDUCE 85
TO 90% OF THE CO2 EMISSIONS

377
00:17:09,466 --> 00:17:10,733
FROM THE STACK.

378
00:17:10,733 --> 00:17:12,633
HOWEVER, IT DOES NOT REDUCE
ANY OF THE EMISSIONS

379
00:17:12,633 --> 00:17:16,500
OF CO2 FROM THE UPSTREAM MINING
AND TRANSPORT OF THE COAL,

380
00:17:16,500 --> 00:17:18,400
WHICH IS ABOUT A THIRD
OF THE EMISSIONS.

381
00:17:18,400 --> 00:17:20,766
IN FACT,
IT INCREASES THAT 25%,

382
00:17:20,766 --> 00:17:22,433
BECAUSE IT TAKES
25% MORE ENERGY.

383
00:17:22,433 --> 00:17:25,600
THAT'S 25% MORE COAL TO RUN
THE CARBON CAPTURE EQUIPMENT.

384
00:17:25,600 --> 00:17:28,933
AND IT ALSO DOES NOT--
THE CARBON CAPTURE EQUIPMENT

385
00:17:28,933 --> 00:17:31,533
DOES NOT REDUCE ANY OF THE OTHER

POLLUTANTS FROM COAL.

386
00:17:31,533 --> 00:17:34,833
IN FACT, IT HAS
TO INCREASE IT 25%.

387
00:17:34,833 --> 00:17:38,200
SO YOU END UP GETTING ABOUT
150 TIMES MORE AIR POLLUTION

388
00:17:38,200 --> 00:17:40,633
PER KILOWATT HOUR THAN WIND.

389
00:17:40,633 --> 00:17:42,166
AND SO IT SHOULD REALLY
BE CALLED DIRTY COAL

390
00:17:42,166 --> 00:17:44,266
RATHER THAN CLEAN COAL.

391
00:17:44,266 --> 00:17:46,900
NOW, WHY NOT WHAT'S CALLED
NUCLEAR POWER?

392
00:17:46,900 --> 00:17:51,566
SO NUCLEAR--WELL, IT SEEMS CLEAN
BECAUSE YOU DON'T HAVE

393
00:17:51,566 --> 00:17:54,466
DIRECT EMISSIONS ASSOCIATED
WITH ITS USE.

394
00:17:54,466 --> 00:17:57,766
HOWEVER, YOU NEED TO MINE
AND REFINE URANIUM CONTINUOUSLY

395
00:17:57,766 --> 00:18:00,500
OVER THE LIFETIME OF THE NUCLEAR
POWER PLANT.

396
00:18:00,500 --> 00:18:03,000
AND THAT'S AN ENERGY-INTENSIVE
PROCESS.

397
00:18:03,000 --> 00:18:07,800
AND THEN IT ALSO TAKES SO LONG
TO PUT UP A NUCLEAR POWER PLANT.

398
00:18:07,800 --> 00:18:11,233
BETWEEN 10 AND 19 YEARS
IN THE U.S.

399
00:18:11,233 --> 00:18:16,200
AND THAT'S BROKEN DOWN INTO
SIX TO TEN YEARS FOR PERMITTING,

400
00:18:16,200 --> 00:18:18,566
AND ANOTHER FOUR TO NINE YEARS
FOR CONSTRUCTION.

401
00:18:18,566 --> 00:18:21,166
AND THIS IS ALL COMPARED
TO ABOUT TWO TO FIVE YEARS TOTAL

402
00:18:21,166 --> 00:18:22,800
FOR A WIND OR SOLAR FARM.

403
00:18:22,800 --> 00:18:24,166
SO WHILE YOU'RE WAITING AROUND

404
00:18:24,166 --> 00:18:25,566
FOR YOUR NUCLEAR PLANT
TO BE PUT UP

405
00:18:25,566 --> 00:18:27,366
YOU'RE RUNNING REGULAR
ELECTRIC POWER GRID,

406
00:18:27,366 --> 00:18:30,100

WHICH IS MOSTLY COAL AND GAS.

407
00:18:30,100 --> 00:18:33,266
AND SO THAT'S AN OPPORTUNITY
COST EMISSIONS.

408
00:18:33,266 --> 00:18:35,833
WHEN YOU COMBINE THAT
WITH THE ENERGY REQUIRED

409
00:18:35,833 --> 00:18:37,666
AND EMISSIONS ASSOCIATED

410
00:18:37,666 --> 00:18:40,033
WITH THE MINING
AND REFINING OF URANIUM,

411
00:18:40,033 --> 00:18:41,700
PLUS THE CONSTRUCTION
OF THE PLANT,

412
00:18:41,700 --> 00:18:43,266
WHICH IS NOT A GREAT
PART OF IT,

413
00:18:43,266 --> 00:18:47,166
YOU GOT ABOUT 9 TO 25 TIMES MORE
CO2 EQUIVALENT EMISSIONS

414
00:18:47,166 --> 00:18:49,633
PER KILOWATT HOUR GENERATED
THAN WIND POWER.

415
00:18:49,633 --> 00:18:51,666
WELL, THERE'S ALSO,
OF COURSE, THE RISK OF MELTDOWN.

416
00:18:51,666 --> 00:18:54,800
1 1/2% OF ALL NUCLEAR REACTORS
EVER BUILT TO DATE

417
00:18:54,800 --> 00:18:56,733
HAVE MELTED DOWN
TO SOME DEGREE.

418
00:18:56,733 --> 00:18:58,600
AND FIVE COUNTRIES
OF THE WORLD

419
00:18:58,600 --> 00:19:00,100
HAVE SECRETLY DEVELOPED
NUCLEAR WEAPONS

420
00:19:00,100 --> 00:19:02,600
UNDER THE GUISE OF CIVILIAN
NUCLEAR ENERGY PROGRAMS.

421
00:19:02,600 --> 00:19:06,366
SO IF YOU WANTED TO POWER
THE ENTIRE WORLD WITH NUCLEAR,

422
00:19:06,366 --> 00:19:11,266
YOU'D NEED ABOUT 16, 17,000
LARGE NUCLEAR POWER PLANTS.

423
00:19:11,266 --> 00:19:13,900
AND WE HAVE ABOUT 440 TODAY.

424
00:19:13,900 --> 00:19:18,400
SO EVEN IF WE DOUBLED THE NUMBER
TODAY TO 800 OR SO,

425
00:19:18,400 --> 00:19:20,533
THAT'D BE ABOUT 5%
OF THE WORLD'S ENERGY.

426
00:19:20,533 --> 00:19:23,666
AND MORE COUNTRIES OF THE WORLD
WOULD POSSIBLY TRY

427
00:19:23,666 --> 00:19:25,466
TO DEVELOP WEAPONS SECRETLY.

428
00:19:25,466 --> 00:19:27,833
SO THERE'S A RISK
OF PROLIFERATION,

429
00:19:27,833 --> 00:19:32,266
WHICH YOU HAVE NO SUCH RISK WITH
WIND/WATER/SOLAR TECHNOLOGIES.

430
00:19:32,266 --> 00:19:34,400
OF COURSE, THERE'S THE
UNRESOLVED WASTE ISSUES.

431
00:19:34,400 --> 00:19:37,166
WELL, WHAT ABOUT BIOFUELS?

432
00:19:37,166 --> 00:19:40,766
WELL, CELLULOSIC ETHANOL
AND CORN ETHANOL

433
00:19:40,766 --> 00:19:44,466
ARE EXAMPLES OF BIOFUELS
THAT HAVE BEEN PROPOSED

434
00:19:44,466 --> 00:19:46,266
TO BE USED
ON LARGE SCALES.

435
00:19:46,266 --> 00:19:50,100
NOW FOR TRANSPORTATION.

436
00:19:50,100 --> 00:19:53,600
BUT JUST TO GIVE YOU AN IDEA
HOW MUCH LAND AREA TAKES ALONE,

437
00:19:53,600 --> 00:19:55,500
LET ALONE ALL THE OTHER ISSUES,

438
00:19:55,500 --> 00:19:58,500
IF YOU WANTED TO POWER
ALL THE U.S. VEHICLES

439
00:19:58,500 --> 00:19:59,900
WITH CELLULOSIC ETHANOL,

440
00:19:59,900 --> 00:20:01,833
WHICH IS A SECOND GENERATION
ETHANOL--

441
00:20:01,833 --> 00:20:03,400
WHICH, BY THE WAY,
DOES NOT ACTUALLY EXIST

442
00:20:03,400 --> 00:20:04,833
AT ANY COMMERCIAL SCALE,

443
00:20:04,833 --> 00:20:07,500
ALTHOUGH IT'S BEEN PROPOSED
SINCE 1980.

444
00:20:07,500 --> 00:20:10,400
THIS IS THE LAND AREA
IT WOULD TAKE,

445
00:20:10,400 --> 00:20:13,100
WHICH IS ON THE ORDER
OF 20% OF THE ENTIRE U.S.,

446
00:20:13,100 --> 00:20:14,766
INCLUDING ALASKA.

447
00:20:14,766 --> 00:20:18,833
AND NOW THERE'S A LOW ESTIMATE
AND A HIGH ESTIMATE HERE:

448
00:20:18,833 --> 00:20:20,766

THE LOW ESTIMATES
FROM THE ETHANOL INDUSTRY

449
00:20:20,766 --> 00:20:22,666
AND THE HIGH ESTIMATES
FROM SOME SCIENCE STUDIES.

450
00:20:22,666 --> 00:20:26,700
BUT THIS IS AN AVERAGE
OF THE TWO.

451
00:20:26,700 --> 00:20:28,333
ANYWAY, SO IT'S A LARGE
LAND AREA.

452
00:20:28,333 --> 00:20:31,833
BUT IF YOU BURN THE ETHANOL,
YOU STILL GET THE SAME POLLUTION

453
00:20:31,833 --> 00:20:33,300
AS YOU DO WITH GASOLINE.

454
00:20:33,300 --> 00:20:36,533
IN FACT, IN TERMS OF OZONE,
IT'S SLIGHTLY WORSE IN THE U.S.

455
00:20:36,533 --> 00:20:38,066
IT DOESN'T MATTER WHERE
THE ETHANOL COMES FROM.

456
00:20:38,066 --> 00:20:41,233
SO YOU ACTUALLY CAUSE ABOUT 4%
HIGHER DEATH RATES IN THE U.S.

457
00:20:41,233 --> 00:20:46,133
FROM OZONE BY USING ETHANOL
OF ANY TYPE THAN GASOLINE.

458
00:20:46,133 --> 00:20:48,666
SO IT'S NOT HELPING IN TERMS

OF AIR POLLUTION.

459
00:20:48,666 --> 00:20:51,866
AND THE CLIMATE BENEFIT
IS KIND OF MARGINAL, BECAUSE--

460
00:20:51,866 --> 00:20:55,300
DEPENDING ON WHETHER OR NOT
YOU COUNT FOR LAND USE CHANGE.

461
00:20:55,300 --> 00:20:57,000
NOW, IN TERMS OF CORN ETHANOL,

462
00:20:57,000 --> 00:20:58,433
THERE'S A LITTLE MORE
UNCERTAINTY.

463
00:20:58,433 --> 00:21:02,166
AND IT'S ABOUT
14% OF THE U.S.

464
00:21:02,166 --> 00:21:04,866
TO POWER THE ENTIRE U.S.
VEHICLE FLEET.

465
00:21:04,866 --> 00:21:06,433
SO IT'S STILL A LARGE AREA.

466
00:21:06,433 --> 00:21:09,166
AND YOU'D REQUIRE ABOUT 13%
OF THE U.S. WATER SUPPLY

467
00:21:09,166 --> 00:21:11,633
TO DO THE SAME THING, AND YOU
HAVE THE AIR POLLUTION ISSUES.

468
00:21:11,633 --> 00:21:15,133
AND PROBABLY THE CLIMATE BENEFIT
IS VIRTUALLY ZERO.

469
00:21:15,133 --> 00:21:18,633
IT'S MAYBE 2-5%, DEPENDING ON
WHOSE STUDY YOU LOOK AT.

470
00:21:18,633 --> 00:21:20,600
IF YOU--NOW, NUCLEAR POWER,

471
00:21:20,600 --> 00:21:22,600
IT WOULD TAKE ABOUT THE SIZE
OF RHODE ISLAND

472
00:21:22,600 --> 00:21:23,900
TO POWER THE SAME
VEHICLE FLEET.

473
00:21:23,900 --> 00:21:25,733
SO THAT'S NOT ONE
OF ITS PROBLEMS,

474
00:21:25,733 --> 00:21:28,100
UNLESS WE WANT TO SACRIFICE
RHODE ISLAND.

475
00:21:28,100 --> 00:21:31,433
BUT IF WE LOOK
AT OTHER OPTIONS...

476
00:21:31,433 --> 00:21:34,500
SO WIND, TO POWER THE WHOLE
U.S. VEHICLE FLEET,

477
00:21:34,500 --> 00:21:36,800
WOULD TAKE--THERE'S TWO TYPES
OF AREAS.

478
00:21:36,800 --> 00:21:38,833
THERE'S THE FOOTPRINT,
WHICH IS THE LAND ON THE GROUND

479

00:21:38,833 --> 00:21:42,166
THAT'S TAKEN UP
BY THE TURBINE TOWER

480
00:21:42,166 --> 00:21:43,933
AND THE CEMENT CASING
AROUND IT.

481
00:21:43,933 --> 00:21:45,533
SO THAT'S REFERRED TO
AS THE FOOTPRINT.

482
00:21:45,533 --> 00:21:46,666
AND THEN THERE'S THE SPACING,

483
00:21:46,666 --> 00:21:48,100
WHICH IS SPACE YOU NEED
BETWEEN TURBINES

484
00:21:48,100 --> 00:21:51,800
TO PREVENT INTERFERENCE
OF ONE TURBINE WITH THE NEXT.

485
00:21:51,800 --> 00:21:55,000
SO THE BLACK ON HERE
IS THE SPACING,

486
00:21:55,000 --> 00:21:56,733
AND THE RED DOT IN THE CENTER
IS THE FOOTPRINT.

487
00:21:56,733 --> 00:21:58,766
SO IT WOULD REQUIRE--

488
00:21:58,766 --> 00:22:03,566
THE SPACING AREA'S ABOUT 1/30
THAT OF CORN ETHANOL

489
00:22:03,566 --> 00:22:05,666
TO POWER THE SAME

VEHICLE FLEET.

490
00:22:05,666 --> 00:22:07,633
AND THE FOOTPRINT AREA'S
ABOUT ONE-MILLIONTH.

491
00:22:07,633 --> 00:22:11,400
IT'S ONLY 1-3 SQUARE KILOMETERS
OF LAND ON THE GROUND

492
00:22:11,400 --> 00:22:13,900
TO POWER THE ENTIRE
U.S. VEHICLE FLEET WITH WIND.

493
00:22:13,900 --> 00:22:18,533
AND THAT WOULD BE WITH ABOUT
73,000 TO 144,000

494
00:22:18,533 --> 00:22:20,866
FIVE-MEGAWATT WIND TURBINES
OPERATING IN WIND SPEEDS

495
00:22:20,866 --> 00:22:23,433
OF 7-8.5 METERS PER SECOND.

496
00:22:23,433 --> 00:22:27,733
WHICH, THOSE WIND SPEEDS YOU CAN
FIND OVER ABOUT 13% OF THE U.S.

497
00:22:27,733 --> 00:22:30,566
SO YOU NEED ONLY ONE-HALF
OF 1% OF THE U.S. LAND AREA

498
00:22:30,566 --> 00:22:33,533
FOR SPACING OF WIND TURBINES
WHERE--

499
00:22:33,533 --> 00:22:35,166
TO POWER THE VEHICLE FLEET.

500
00:22:35,166 --> 00:22:37,300
AND YOU HAVE ABOUT 13%.

501
00:22:37,300 --> 00:22:42,666
SO YOU HAVE 26 TIMES MORE AREA
THAN YOU NEED FOR--TO DO THAT.

502
00:22:42,666 --> 00:22:44,700
NOW, A LOT OF THIS
COULD ALSO GO OFFSHORE,

503
00:22:44,700 --> 00:22:47,266
WHERE YOU HAVE EVEN MORE WIND
AND MORE SPACE.

504
00:22:47,266 --> 00:22:51,800
NOW, IN TERMS
OF OTHER SOLAR P.V.

505
00:22:51,800 --> 00:22:53,733
TO POWER BATTERY-ELECTRIC
VEHICLES

506
00:22:53,733 --> 00:22:55,900
WOULD TAKE ONE-THIRD THE SPACING
AREA OF WIND,

507
00:22:55,900 --> 00:22:58,366
BUT IF IT'S NOT ON ROOFTOPS--

508
00:22:58,366 --> 00:23:01,366
AND YOU CAN'T PUT IT ALL
ON ROOFTOPS, AS I'LL SHOW LATER.

509
00:23:01,366 --> 00:23:04,166
--THEN YOU WOULD BE...

510
00:23:04,166 --> 00:23:06,333
IT'S MORE FOOTPRINT,

BUT LESS SPACING.

511
00:23:06,333 --> 00:23:09,900
AND GEOTHERMAL WOULD TAKE EVEN
LESS SPACING AREA THAN WIND,

512
00:23:09,900 --> 00:23:11,400
BUT STILL MORE FOOTPRINT.

513
00:23:11,400 --> 00:23:14,266
BUT WE'RE GOING TO BE LOOKING
AT WIND AND GEOTHERMAL AND SOLAR

514
00:23:14,266 --> 00:23:15,633
AS POSSIBLE OPTIONS,

515
00:23:15,633 --> 00:23:17,900
SO THEY ALL TAKE RELATIVELY
LITTLE SPACE TO DO THIS,

516
00:23:17,900 --> 00:23:19,366
TO RUN THE VEHICLE FLEET.

517
00:23:19,366 --> 00:23:20,600
BUT WE'RE GOING
TO BE LOOKING NOW

518
00:23:20,600 --> 00:23:23,000
AT POWERING THE ENTIRE U.S.
FOR ALL PURPOSES.

519
00:23:23,000 --> 00:23:25,066
SO LET'S GIVE
SOME OVERALL NUMBERS,

520
00:23:25,066 --> 00:23:27,066
WORLDWIDE AND IN THE U.S.

521
00:23:27,066 --> 00:23:30,100

SO IN 2010, THE END-USE POWER
DEMAND WORLDWIDE

522
00:23:30,100 --> 00:23:32,233
IN TERAWATTS,
OR A TRILLION WATTS.

523
00:23:32,233 --> 00:23:34,733
THIS IS END USES,
INCLUDING ELECTRICITY,

524
00:23:34,733 --> 00:23:37,366
TRANSPORTATION, HEATING
AND COOLING, AND INDUSTRY,

525
00:23:37,366 --> 00:23:39,666
AND WHAT PEOPLE ACTUALLY USE
TO RUN THINGS.

526
00:23:39,666 --> 00:23:41,400
IT'S ABOUT 13 TERAWATTS.

527
00:23:41,400 --> 00:23:43,266
IF YOU GO TO 2050,

528
00:23:43,266 --> 00:23:46,000
THE PROJECTION IS ABOUT
21.6 TERAWATTS.

529
00:23:46,000 --> 00:23:48,666
BUT IF YOU CONVERT EVERYTHING
TO WIND/WATER/SOLAR,

530
00:23:48,666 --> 00:23:51,300
AND ELECTRICITY
AND ELECTROLYTIC HYDROGEN,

531
00:23:51,300 --> 00:23:54,266
YOU GO DOWN ABOUT 30%
OF YOUR POWER DEMAND.

532
00:23:54,266 --> 00:23:57,366
AND ONLY ABOUT 5 PERCENTAGE
POINTS OF THIS 30%

533
00:23:57,366 --> 00:24:00,400
IS DUE TO END-USE
ENERGY EFFICIENCY IMPROVEMENTS.

534
00:24:00,400 --> 00:24:05,166
THE 25% IS DUE TO THE EFFICIENCY
OF ELECTRICITY OVER COMBUSTION.

535
00:24:05,166 --> 00:24:07,633
AND YOU CAN TELL ABOUT THIS
ELECTRICITY EFFICIENCY

536
00:24:07,633 --> 00:24:11,066
BY WHEN YOU LOOK AT CONVERTING
TRANSPORTATION.

537
00:24:11,066 --> 00:24:14,600
SO THE PLUG-TO-WHEEL EFFICIENCY
OF AN ELECTRIC CAR

538
00:24:14,600 --> 00:24:16,233
IS ABOUT 80 TO 86%.

539
00:24:16,233 --> 00:24:19,633
IN OTHER WORDS, 80 TO 86% OF
THE ELECTRICITY GOING INTO A CAR

540
00:24:19,633 --> 00:24:20,900
GOES TO MOVE THE CAR.

541
00:24:20,900 --> 00:24:22,466
THE REST IS WASTE HEAT.

542
00:24:22,466 --> 00:24:24,500

AND IN AN INTERNAL
COMBUSTION ENGINE,

543
00:24:24,500 --> 00:24:29,166
THE TANK-TO-WHEEL EFFICIENCY
IS ABOUT 17-20%.

544
00:24:29,166 --> 00:24:31,700
SO ABOUT 80-83%
OF THE ENERGY IN THE GASOLINE

545
00:24:31,700 --> 00:24:35,966
IS WASTED AS HEAT,
AND 17-20% GOES TO MOVE THE CAR.

546
00:24:35,966 --> 00:24:39,533
SO YOU USE ONE-FOURTH
TO ONE-FIFTH THE ENERGY

547
00:24:39,533 --> 00:24:41,800
DRIVING AN ELECTRIC CAR
THE SAME DISTANCE

548
00:24:41,800 --> 00:24:43,666
AS DRIVING A GASOLINE CAR.

549
00:24:43,666 --> 00:24:46,633
SO IT COSTS ABOUT ONE-FOURTH
TO ONE-FIFTH

550
00:24:46,633 --> 00:24:49,000
TO DRIVE THE ELECTRIC CAR
IN TERMS OF THE FUEL.

551
00:24:49,000 --> 00:24:51,800
SO IN OTHER WORDS, IT'S ABOUT
80 CENTS A GALLON EQUIVALENT

552
00:24:51,800 --> 00:24:53,466
FOR DRIVING AN ELECTRIC CAR

553
00:24:53,466 --> 00:24:56,066
COMPARED TO $4 A GALLON
FOR A GASOLINE CAR.

554
00:24:56,066 --> 00:24:58,733
SO IF YOU DROVE
AN ELECTRIC CAR FOR 15 YEARS,

555
00:24:58,733 --> 00:25:00,600
15,000 MILES PER YEAR,

556
00:25:00,600 --> 00:25:04,033
YOU WOULD SAVE ABOUT $20,000
IN FUEL COSTS.

557
00:25:04,033 --> 00:25:05,533
AND THAT'S BECAUSE
OF THE EFFICIENCY.

558
00:25:05,533 --> 00:25:07,600
SO TRANSPORTATION'S
ONE SECTOR

559
00:25:07,600 --> 00:25:09,300
WHERE YOU GET
MOST OF THE EFFICIENCY.

560
00:25:09,300 --> 00:25:12,600
SO THAT'S WHY, JUST BY
CONVERTING TO ELECTRICITY,

561
00:25:12,600 --> 00:25:14,566
YOU REDUCE YOUR ENERGY USE.

562
00:25:14,566 --> 00:25:17,066
AND IN THE U.S., BECAUSE THERE'S
MORE TRANSPORTATION

563

00:25:17,066 --> 00:25:18,933
IN THE WORLD AS A WHOLE,

564
00:25:18,933 --> 00:25:23,900
YOU GO DOWN 40--SORRY, 37.6%
IN YOUR ENERGY DEMAND.

565
00:25:23,900 --> 00:25:26,066
AND ABOUT 5 PERCENTAGE POINTS
OF THAT IS, AGAIN,

566
00:25:26,066 --> 00:25:27,566
END-USE EFFICIENCY.

567
00:25:27,566 --> 00:25:28,900
IN CALIFORNIA,

568
00:25:28,900 --> 00:25:30,600
BECAUSE THERE'S MORE
TRANSPORTATION IN CALIFORNIA

569
00:25:30,600 --> 00:25:32,266
THAN EVEN IN THE U.S.,

570
00:25:32,266 --> 00:25:34,733
THAT'S ABOUT 44% REDUCTION
IN POWER DEMAND

571
00:25:34,733 --> 00:25:36,300
JUST BY GOING
TO ELECTRICITY.

572
00:25:36,300 --> 00:25:39,566
SO HERE'S ONE WAY
TO POWER THE WORLD

573
00:25:39,566 --> 00:25:41,966
WITH THESE WIND/WATER/SOLAR
TECHNOLOGIES.

574
00:25:41,966 --> 00:25:44,166
THIS IS FOR 2030.

575
00:25:44,166 --> 00:25:48,066
THIS WOULD BE 50% WIND,
40% SOLAR.

576
00:25:48,066 --> 00:25:51,733
AND THE SOLAR WOULD BE DIVIDED
INTO A ROOFTOP SYSTEM: 6%.

577
00:25:51,733 --> 00:25:55,000
P.V. POWER PLANTS:
ABOUT 14%.

578
00:25:55,000 --> 00:25:56,933
AND C.S.P. POWER PLANTS:
ABOUT 20%.

579
00:25:56,933 --> 00:26:01,200
ALTHOUGH THEY PROBABLY REVISED
THOSE DISTRIBUTIONS NOW.

580
00:26:01,200 --> 00:26:04,966
AND ABOUT 10% FOR EVERYTHING
ELSE, INCLUDING 4% HYDRO,

581
00:26:04,966 --> 00:26:08,400
4% GEOTHERMAL,
1% WAVE AND TIDAL.

582
00:26:08,400 --> 00:26:10,400
AND SO THE WIND
WOULD BE ABOUT

583
00:26:10,400 --> 00:26:13,066
3.8 MILLION FIVE-MEGAWATT
WIND TURBINES.

584

00:26:13,066 --> 00:26:15,666
SOUNDS LIKE A LOT,
BUT, YOU KNOW,

585
00:26:15,666 --> 00:26:18,066
THIS IS TO POWER HALF THE WORLD
FOR ALL PURPOSES.

586
00:26:18,066 --> 00:26:20,400
THAT'S EVERYTHING IN 2030.

587
00:26:20,400 --> 00:26:22,866
AND, YOU KNOW,
THE U.S. IN WORLD WAR II

588
00:26:22,866 --> 00:26:25,866
PRODUCED ABOUT 330,000 AIRCRAFT
EACH YEAR,

589
00:26:25,866 --> 00:26:27,166
AND THE WORLD PRODUCED--

590
00:26:27,166 --> 00:26:29,933
SORRY, 330,000 AIRCRAFT
DURING THE WHOLE WAR.

591
00:26:29,933 --> 00:26:32,700
AND THE WORLD PRODUCED
ABOUT 800,000.

592
00:26:32,700 --> 00:26:34,533
AND EVERY YEAR,
THE WORLD PRODUCES

593
00:26:34,533 --> 00:26:37,033
ABOUT 70 MILLION
AUTOMOBILES.

594
00:26:37,033 --> 00:26:39,933
SO JUST PRODUCING 4 MILLION

WIND TURBINES

595
00:26:39,933 --> 00:26:42,766
TO POWER HALF THE WORLD
SHOULD NOT BE A GREAT FEAT.

596
00:26:42,766 --> 00:26:46,133
BUT, YOU KNOW, THERE'S A LOT OF
POLITICS GOING INTO PLAY HERE.

597
00:26:46,133 --> 00:26:48,500
SO LET'S LOOK AT IT
A LITTLE MORE CLOSELY.

598
00:26:48,500 --> 00:26:50,233
WHAT ABOUT THE U.S.?

599
00:26:50,233 --> 00:26:53,233
TO POWER THE ENTIRE
UNITED STATES FOR ALL PURPOSES--

600
00:26:53,233 --> 00:26:55,233
AND THIS IS BASED ON
WE ACTUALLY DID PLANS

601
00:26:55,233 --> 00:26:56,633
FOR EVERY SINGLE STATE
INDIVIDUALLY,

602
00:26:56,633 --> 00:26:58,433
AND THIS IS THE SUM--
SUM RESULT.

603
00:26:58,433 --> 00:27:00,933
AND I'LL SHOW YOU A MAP
OF THE RESULTS.

604
00:27:00,933 --> 00:27:02,866
UH, WE WOULD--

605
00:27:02,866 --> 00:27:04,066
THIS IS ONE WAY TO DO IT,

606
00:27:04,066 --> 00:27:05,500
AND YOU CAN DO IT
IN OTHER WAYS TOO.

607
00:27:05,500 --> 00:27:09,966
THIS WOULD BE 31% ONSHORE WIND,
19% OFFSHORE WIND.

608
00:27:09,966 --> 00:27:14,133
AND THEN RESIDENTIAL ROOFTOP
SYSTEM, ALMOST 5%.

609
00:27:14,133 --> 00:27:18,066
COMMERCIAL GOVERNMENT
P.V. ROOFTOP SYSTEMS, ABOUT 4%.

610
00:27:18,066 --> 00:27:20,866
SO IN THE ORDER OF 8 1/2%
ROOFTOP SOLAR.

611
00:27:20,866 --> 00:27:22,533
NOW, WE ACTUALLY WENT THROUGH
EVERY STATE

612
00:27:22,533 --> 00:27:25,333
AND CALCULATED THE ROOFTOP AREAS
IN EVERY STATE.

613
00:27:25,333 --> 00:27:28,133
AND INCLUDING THE PARKING
STRUCTURE, POTENTIAL AREAS,

614
00:27:28,133 --> 00:27:30,300
AND THEN PROJECTED TO 2050
TO GET THESE NUMBERS.

615

00:27:30,300 --> 00:27:32,766
SO THIS IS ABOUT--THIS IS
SATURATING ALL THE ROOFS.

616
00:27:32,766 --> 00:27:36,366
SO YOU COULD POWER
FOR THE WHOLE--ALL PURPOSES

617
00:27:36,366 --> 00:27:40,100
U.S. IN 2050 WITH PROBABLY NO
MORE THAN 8 1/2 OR 9%.

618
00:27:40,100 --> 00:27:43,033
YOU MIGHT BE ABLE TO SQUEEZE
UP TO 10% ROOFTOP SOLAR.

619
00:27:43,033 --> 00:27:45,500
SO WE WANT TO DO AS MUCH
AS POSSIBLE.

620
00:27:45,500 --> 00:27:46,900
IF WE CAN DO MORE,
THAT'S GREAT.

621
00:27:46,900 --> 00:27:49,666
BUT YOU'RE NOT GOING TO BE ABLE
TO DISTRIBUTE IT.

622
00:27:49,666 --> 00:27:51,266
ENERGY CAN ONLY GO
SO FAR.

623
00:27:51,266 --> 00:27:53,500
YOU WILL NEED POWER PLANTS
AS WELL.

624
00:27:53,500 --> 00:27:57,666
SO THAT'S WHY WE HAVE POWER
PLANT P.V.'S, LIKE IN DESERTS,

625

00:27:57,666 --> 00:28:00,633
AND CONCENTRATED SOLAR POWER
IN DESERTS.

626
00:28:00,633 --> 00:28:05,566
SO ABOUT 29.6% OF THE PLANT HERE
ACROSS STATES

627
00:28:05,566 --> 00:28:07,733
IS SOLAR P.V. PLANTS.

628
00:28:07,733 --> 00:28:12,266
ANOTHER 8% IS C.S.P.,
OR CONCENTRATED SOLAR PLANTS.

629
00:28:12,266 --> 00:28:15,066
AND THEN GEOTHERMAL'S
ABOUT 1.3%.

630
00:28:15,066 --> 00:28:19,533
THIS IS ACCOUNTING FOR POTENTIAL
GROWTH OF GEOTHERMAL.

631
00:28:19,533 --> 00:28:21,833
AND HYDRO IS ABOUT 2.5%.

632
00:28:21,833 --> 00:28:23,300
NOW, THIS IS NOT JUST
ELECTRICITY.

633
00:28:23,300 --> 00:28:25,300
AGAIN, THIS IS ALL POWER.

634
00:28:25,300 --> 00:28:29,933
RIGHT NOW HYDRO POWERS ABOUT
6 1/2% OF ALL U.S. ELECTRICITY.

635
00:28:29,933 --> 00:28:33,566
BUT ELECTRICITY IS ONLY
ABOUT ONE-FIFTH OF TOTAL ENERGY.

636
00:28:33,566 --> 00:28:38,533
SO IT'S ONLY PRODUCING ABOUT
1%, 1 1/2% OF TOTAL ENERGY.

637
00:28:38,533 --> 00:28:41,366
AND SO WE'D BE DOUBLING,
BASICALLY, THE HYDRO

638
00:28:41,366 --> 00:28:43,133
WITHOUT ACTUALLY INCREASING
ANY PLANTS.

639
00:28:43,133 --> 00:28:46,800
THIS PLAN HAS VIRTUALLY
NO INCREASE

640
00:28:46,800 --> 00:28:48,300
IN THE NUMBER
OF HYDROELECTRIC PLANTS,

641
00:28:48,300 --> 00:28:50,033
EXCEPT FOR IN ALASKA,
WHERE THERE'S--

642
00:28:50,033 --> 00:28:53,100
THOSE FOUR PLANTS LISTED THERE
WOULD ALL BE IN ALASKA,

643
00:28:53,100 --> 00:28:56,533
BECAUSE WE'RE JUST PLANNING
TO HAVE THE EXISTING HYDRO,

644
00:28:56,533 --> 00:28:58,233
BUT INCREASE
THE EFFICIENCY,

645
00:28:58,233 --> 00:29:02,000
POSSIBLY TAKING SOME NON-POWER
DAMS AND MAKING THEM POWER DAMS,

646
00:29:02,000 --> 00:29:04,400
BUT NOT ACTUALLY PUTTING
NEW DAMS IN.

647
00:29:04,400 --> 00:29:06,966
THEN THERE'S A SMALL AMOUNT
OF TIDAL WAVE POWER.

648
00:29:06,966 --> 00:29:09,333
SO HOW MUCH LAND AREA
DOES THIS TAKE?

649
00:29:09,333 --> 00:29:11,866
SO THIS IS THE LAND AREA
REQUIRED.

650
00:29:11,866 --> 00:29:15,100
THE GREEN IN THE CENTER
IS FOR ONSHORE WIND,

651
00:29:15,100 --> 00:29:16,466
AND THAT'S MOSTLY SPACING AREA,

652
00:29:16,466 --> 00:29:20,133
WHICH IS 31% OF THE TOTAL
ENERGY OF POWER.

653
00:29:20,133 --> 00:29:23,166
THE FOOTPRINT WOULD BE
ABOUT 4 1/2 SQUARE KILOMETERS

654
00:29:23,166 --> 00:29:24,900
ON THE GROUND.

655
00:29:24,900 --> 00:29:28,500
AND THE SPACING AREA'S
ABOUT 1.7% OF THE U.S.

656

00:29:28,500 --> 00:29:31,900
OFFSHORE WIND IS ABOUT 19%
OF THE TOTAL.

657
00:29:31,900 --> 00:29:36,333
P.V. PLUS C.S.P. POWER PLANTS
IS 37%, AND THAT ORANGE DOT--

658
00:29:36,333 --> 00:29:40,066
BUT THE LAND AREA IS ABOUT .4%
OF THE U.S.

659
00:29:40,066 --> 00:29:43,400
ROOFTOP P.V., WHICH WOULD NOT
REQUIRE NEW LAND,

660
00:29:43,400 --> 00:29:48,033
IS ABOUT 9% OF THE TOTAL
POWER SUPPLY,

661
00:29:48,033 --> 00:29:50,766
AND ABOUT .09%
OF THE LAND AREA.

662
00:29:50,766 --> 00:29:53,566
AND THEN THERE'S A SMALL AMOUNT
OF HYDRO AND TIDAL WAVE.

663
00:29:53,566 --> 00:29:56,633
JUST ONE MORE OF THESE.
HERE'S FOR CALIFORNIA.

664
00:29:56,633 --> 00:30:00,000
CALIFORNIA WOULD BE DOMINATED
MORE BY SOLAR, IN THIS CASE.

665
00:30:00,000 --> 00:30:02,066
BUT STILL,
35% TOTAL WIND,

666

00:30:02,066 --> 00:30:05,133
WITH 25% ONSHORE WIND
AND 10% OFFSHORE.

667
00:30:05,133 --> 00:30:09,266
ROOFTOP SOLAR AND BUILDING
COMMERCIAL GOVERNMENT--

668
00:30:09,266 --> 00:30:11,133
BUILDING SOLAR,
ABOUT 14% TOTAL--

669
00:30:11,133 --> 00:30:15,566
OF THE TOTAL ENERGY
WOULD BE PROVIDED FROM THERE.

670
00:30:15,566 --> 00:30:17,733
P.V. POWER PLANTS: 26%.

671
00:30:17,733 --> 00:30:19,700
15% C.S.P. POWER PLANTS.

672
00:30:19,700 --> 00:30:22,166
5% GEOTHERMAL,
3 1/2% HYDRO.

673
00:30:22,166 --> 00:30:23,733
AGAIN, NO NEW DAMS.

674
00:30:23,733 --> 00:30:26,066
AND A SMALL AMOUNT
OF TIDAL WAVE.

675
00:30:26,066 --> 00:30:29,500
AND HERE'S--THIS IS WHAT
THE LAND AREA'S REQUIRED

676
00:30:29,500 --> 00:30:33,200
AND WATER AREA'S REQUIRED
FOR CALIFORNIA ENERGY PLAN.

677
00:30:33,200 --> 00:30:35,200
AND SO, AGAIN,
WE DO THIS FOR ALL 50 STATES

678
00:30:35,200 --> 00:30:38,600
WELL, IN THESE PLANS, THERE'D BE
A LOT OF OFFSHORE WIND.

679
00:30:38,600 --> 00:30:43,366
AND WE DID A STUDY,
A COMPUTER MODELING STUDY,

680
00:30:43,366 --> 00:30:44,700
LOOKING AT, WELL,
WHAT'S THE IMPACT?

681
00:30:44,700 --> 00:30:46,133
BECAUSE YOU MIGHT ASK--

682
00:30:46,133 --> 00:30:48,966
IF YOU HAVE A LOT
OF WIND TURBINES,

683
00:30:48,966 --> 00:30:50,500
DO THEY INTERFERE
WITH EACH OTHER?

684
00:30:50,500 --> 00:30:52,966
MAYBE THEY TAKE TOO MUCH ENERGY
OUT OF THE WIND,

685
00:30:52,966 --> 00:30:57,033
AND THEREFORE CAN'T PROVIDE
ALL THE ENERGY.

686
00:30:57,033 --> 00:30:59,000
WE DID ONE STUDY ON THAT
LOOKING AT

687
00:30:59,000 --> 00:31:02,266
IF YOU SATURATE THE U.S. AND
THE WORLD WITH WIND TURBINES,

688
00:31:02,266 --> 00:31:04,533
WOULD YOU HAVE ENOUGH ENERGY
STILL TO POWER THE WORLD?

689
00:31:04,533 --> 00:31:07,700
BECAUSE EACH TURBINE TAKES
ENERGY FROM OTHER TURBINES.

690
00:31:07,700 --> 00:31:09,966
BUT WE FOUND THAT THERE--

691
00:31:09,966 --> 00:31:11,633
WELL, IN THE WORLD--

692
00:31:11,633 --> 00:31:14,300
YOU CAN COVER THE ENTIRE WORLD
WITH WIND TURBINES,

693
00:31:14,300 --> 00:31:16,700
AND THE MOST ENERGY
OR POWER YOU CAN EXTRACT

694
00:31:16,700 --> 00:31:19,466
IS ABOUT 250 TERAWATTS
WORLDWIDE.

695
00:31:19,466 --> 00:31:21,600
THAT'S OVER LAND AND OCEAN.

696
00:31:21,600 --> 00:31:23,800
AND WE NEED ABOUT...

697
00:31:23,800 --> 00:31:28,800
ON THE ORDER OF 12 OR SO
TERAWATTS OF POWER.

698
00:31:28,800 --> 00:31:31,466
AND SO--TO POWER
THE ENTIRE WORLD.

699
00:31:31,466 --> 00:31:33,233
SO THERE'S PLENTY
OF WIND WORLDWIDE

700
00:31:33,233 --> 00:31:34,766
TO POWER THE ENTIRE WORLD,
EVEN IF YOU SET--

701
00:31:34,766 --> 00:31:36,966
EVEN IF YOU HAVE TURBINES
RIGHT NEXT TO EACH OTHER.

702
00:31:36,966 --> 00:31:39,033
OVER LAND,
THERE'S ABOUT 80 TERAWATTS

703
00:31:39,033 --> 00:31:42,300
OF WIND POWER AVAILABLE
WORLDWIDE.

704
00:31:42,300 --> 00:31:45,433
SO IT'S NOT--WE WON'T
RUN OUT OF WIND.

705
00:31:45,433 --> 00:31:49,533
BUT THE KEY IS TO HAVE WIND
FARMS SEPARATED FROM EACH OTHER

706
00:31:49,533 --> 00:31:52,633
SO WIND FARMS THEMSELVES
DON'T INTERFERE WITH EACH OTHER.

707
00:31:52,633 --> 00:31:55,333
YOU CAN HAVE A LOT OF INDIVIDUAL
TURBINES IN A WIND FARM,

708
00:31:55,333 --> 00:31:58,500
BUT YOU WANT TO SEPARATE
THE WIND FARMS FAR ENOUGH APART.

709
00:31:58,500 --> 00:32:00,733
BUT ANOTHER QUESTION THAT AROSE
IS, "WELL, WHAT'S THE IMPACT?"

710
00:32:00,733 --> 00:32:02,733
IF YOU HAVE A LOT OF OFFSHORE
WINDS OFF THE EAST COAST,

711
00:32:02,733 --> 00:32:04,066
YOU GET A LOT OF HURRICANES.

712
00:32:04,066 --> 00:32:05,733
WON'T THE HURRICANES
DESTROY THE WIND TURBINES?

713
00:32:05,733 --> 00:32:09,266
AND SO WE THOUGHT
ABOUT THIS,

714
00:32:09,266 --> 00:32:11,300
AND THEN LOOKED
AT THE QUESTION.

715
00:32:11,300 --> 00:32:13,700
WELL, THE TURBINES
MIGHT BE DESTROYED.

716
00:32:13,700 --> 00:32:15,300
BUT ON THE OTHER HAND,
IF YOU HAVE ENOUGH TURBINES,

717
00:32:15,300 --> 00:32:17,266
MAYBE THEY'LL FEED BACK
AND EXTRACT ENOUGH ENERGY

718
00:32:17,266 --> 00:32:19,200
FROM THE HURRICANES.

719
00:32:19,200 --> 00:32:23,533
SO WE DID A CASE WHERE WE PUT
WIND TURBINES

720
00:32:23,533 --> 00:32:28,533
IN A 3D WEATHER MODEL
OFF THE COAST OF NEW ORLEANS.

721
00:32:28,533 --> 00:32:31,266
AND WE LOOKED
AT HURRICANE SANDY--

722
00:32:31,266 --> 00:32:33,366
WELL, HURRICANE KATRINA
AND ISAAC OFF NEW ORLEANS,

723
00:32:33,366 --> 00:32:36,766
AND HURRICANE SANDY OFF
NEW YORK AND THE EAST COAST.

724
00:32:36,766 --> 00:32:38,866
AND HERE'S ONE OF THE RESULTS.

725
00:32:38,866 --> 00:32:41,666
SO IN THIS CASE
WE HAVE TWO HURRICANE--

726
00:32:41,666 --> 00:32:44,100
OF THE SAME HURRICANE:
HURRICANE KATRINA.

727
00:32:44,100 --> 00:32:45,933
THE LEFT SIDE
IS NO WIND TURBINES.

728
00:32:45,933 --> 00:32:50,800

ON THE RIGHT SIDE WE HAD 170,000
OF 7 1/2-MEGAWATT TURBINES

729
00:32:50,800 --> 00:32:52,933
TO THE SOUTHEAST
OF NEW ORLEANS.

730
00:32:52,933 --> 00:32:57,533
AND WE THEN RAN--
PRODUCED THE HURRICANE.

731
00:32:57,533 --> 00:32:59,033
WE COMPARED THE HURRICANE
WITH DATA

732
00:32:59,033 --> 00:33:00,700
WHEN THERE WERE NO TURBINES.

733
00:33:00,700 --> 00:33:03,433
THEN WHAT WE FOUND
IS THE HURRICANE--

734
00:33:03,433 --> 00:33:07,133
THE HURRICANES WERE BEING
DIMINISHED BY--

735
00:33:07,133 --> 00:33:09,466
WHEN YOU HAVE LARGE ARRAYS
OF OFFSHORE WIND.

736
00:33:09,466 --> 00:33:11,833
SO IN THIS CASE,
YOU CAN SEE IN THE RIGHT,

737
00:33:11,833 --> 00:33:14,300
THAT'S KIND OF WHERE
THAT TRIANGLE IS,

738
00:33:14,300 --> 00:33:16,400
THAT'S WHERE THE TURBINES

WERE LOCATED.

739
00:33:16,400 --> 00:33:17,933
AND WHAT HAPPENS IS,

740
00:33:17,933 --> 00:33:20,566
THE TURBINES WOULD EXTRACT
ENERGY FROM THE HURRICANE,

741
00:33:20,566 --> 00:33:23,633
SLOW THE WIND SPEEDS LOCALLY,
REDUCE THE WAVE HEIGHTS,

742
00:33:23,633 --> 00:33:25,433
REDUCE CONVERGENCE,
BECAUSE YOU NEED WAVES

743
00:33:25,433 --> 00:33:28,266
TO PRODUCE FRICTION THAT CAUSES
CONVERGENCE OF AIR

744
00:33:28,266 --> 00:33:29,833
TO THE CENTER
OF THE HURRICANE.

745
00:33:29,833 --> 00:33:33,400
SO WHEN YOU REDUCE
THE WIND SPEEDS LOCALLY,

746
00:33:33,400 --> 00:33:35,100
YOU REDUCE WAVE HEIGHT,
YOU REDUCE FRICTION.

747
00:33:35,100 --> 00:33:36,866
SO YOU REDUCE CONVERGENCE
TO THE CENTER.

748
00:33:36,866 --> 00:33:38,633
SO YOU INCREASE
THE ESSENTIAL PRESSURE.

749
00:33:38,633 --> 00:33:41,900
AND THAT CAUSED A DIMINISHMENT
OF THE ENTIRE HURRICANE

750
00:33:41,900 --> 00:33:44,666
SUCH THAT BY THE TIME THE CORE
GOT TO NEW ORLEANS,

751
00:33:44,666 --> 00:33:47,033
THE WHOLE THING
WAS PRETTY MUCH DIMINISHED.

752
00:33:47,033 --> 00:33:52,033
AND, IN FACT, IT REDUCED ABOUT
80% OF THE STORM SURGE,

753
00:33:52,033 --> 00:33:56,200
AND OVER IN 50 TO 60%
OF THE WIND SPEED

754
00:33:56,200 --> 00:33:58,100
AT NEW ORLEANS.
AND WE FOUND THIS--

755
00:33:58,100 --> 00:34:00,500
FOR ALL THE HURRICANES
THAT WE TESTED,

756
00:34:00,500 --> 00:34:01,800
WE FOUND THIS RESULT.

757
00:34:01,800 --> 00:34:03,833
AND ALSO, THE WIND SPEEDS,
IN FACT,

758
00:34:03,833 --> 00:34:05,166
WHEN YOU HAD ENOUGH OF THEM,

759

00:34:05,166 --> 00:34:07,566
NEVER GOT UP TO THE DESTRUCTION
OF WIND SPEED

760
00:34:07,566 --> 00:34:10,100
OF THE TURBINES,
WHICH IS 50 METERS PER SECOND,

761
00:34:10,100 --> 00:34:14,666
BECAUSE YOU FEED BACK TO THE
CENTER OF THE HURRICANE SO MUCH

762
00:34:14,666 --> 00:34:17,266
THAT YOU JUST DIMINISH
ALL THE WINDS LOCALLY.

763
00:34:17,266 --> 00:34:20,933
AND I CAN GO INTO DETAIL NOW,
BUT I DON'T HAVE TIME.

764
00:34:20,933 --> 00:34:23,933
BUT...SO THE RESULT WAS

765
00:34:23,933 --> 00:34:26,800
THAT IF YOU HAVE LARGE ARRAYS,
YOU CAN HAVE THIS IMPACT.

766
00:34:26,800 --> 00:34:28,333
YOU CAN HAVE A BENEFIT.

767
00:34:28,333 --> 00:34:30,900
NOW YOU MIGHT SAY, "WELL, THAT'S
GOING TO BE REALLY EXPENSIVE."

768
00:34:30,900 --> 00:34:32,766
BUT THE THING IS,
YOU PUT UP THE TURBINES

769
00:34:32,766 --> 00:34:34,566
TO GENERATE NORMAL ELECTRIC

POWER YEAR-ROUND.

770
00:34:34,566 --> 00:34:36,500
SO THEY PAY FOR THEMSELVES.

771
00:34:36,500 --> 00:34:41,000
AND SO AS A RESULT,
IT WOULD NOT COST EXTRA

772
00:34:41,000 --> 00:34:42,333
TO PREVENT THE HURRICANE,

773
00:34:42,333 --> 00:34:44,866
OR REDUCE THE DAMAGE
OF THE HURRICANE.

774
00:34:44,866 --> 00:34:47,733
UM, ON THE OTHER HAND,
IF YOU PUT UP SEA WALLS,

775
00:34:47,733 --> 00:34:50,266
THEY MIGHT COST $30 BILLION
FOR ONE CITY.

776
00:34:50,266 --> 00:34:51,666
THEY DON'T GENERATE
ELECTRICITY,

777
00:34:51,666 --> 00:34:53,466
SO THEY DON'T PAY
FOR THEMSELVES.

778
00:34:53,466 --> 00:34:55,266
AND THEY DON'T ACTUALLY REDUCE
WIND SPEEDS.

779
00:34:55,266 --> 00:34:57,200
THEY ONLY REDUCE
STORM SURGE.

780
00:34:57,200 --> 00:34:59,166
AND SO YOU CAN TAKE
$30 BILLION

781
00:34:59,166 --> 00:35:01,400
AND JUST BUY WIND TURBINES
WITH THEM,

782
00:35:01,400 --> 00:35:04,866
AND GET THAT MONEY BACK
OVER TIME.

783
00:35:04,866 --> 00:35:08,300
SO I THINK IT'S PROBABLY
A BETTER INVESTMENT

784
00:35:08,300 --> 00:35:09,866
TO GO WITH OFFSHORE WIND.

785
00:35:09,866 --> 00:35:12,766
NOW IF YOU DON'T HAVE ENOUGH
TURBINES, YOU DO RUN MORE RISK

786
00:35:12,766 --> 00:35:16,133
OF TURBINE DESTRUCTION
IN THE GULF COAST,

787
00:35:16,133 --> 00:35:17,700
BUT NOT THE EAST COAST,
BECAUSE IN THE EAST COAST

788
00:35:17,700 --> 00:35:20,033
THE HURRICANES ARE NEVER--
THE WIND SPEEDS NEVER GET UP

789
00:35:20,033 --> 00:35:23,233
TO THE DESTRUCTION WIND SPEED
OF THE TURBINE IN ANY CASE.

790

00:35:23,233 --> 00:35:25,733
ANYWAY, I'M GOING TO MOVE ON
FROM THAT.

791
00:35:25,733 --> 00:35:29,233
SO, WHAT ABOUT THE COSTS
OF ENERGY

792
00:35:29,233 --> 00:35:32,633
IF WE DO THIS CONVERSION
TO WIND, WATER AND SOLAR?

793
00:35:32,633 --> 00:35:35,033
WELL, ON THE LEFT SIDE HERE
IS THE CURRENT COST

794
00:35:35,033 --> 00:35:38,000
OF THESE DIFFERENT
CLEAN ENERGY TECHNOLOGIES.

795
00:35:38,000 --> 00:35:41,500
FOR WIND, IT'S 4 TO 10 CENTS
A KILOWATT HOUR.

796
00:35:41,500 --> 00:35:43,300
THAT'S ONSHORE WIND.

797
00:35:43,300 --> 00:35:46,966
OFFSHORE WIND'S 11-22 CENTS.
GEOTHERMAL'S ABOUT 10-15 CENTS.

798
00:35:46,966 --> 00:35:49,200
HYDRO IS ABOUT 4-6 CENTS
A KILOWATT HOUR.

799
00:35:49,200 --> 00:35:53,100
CONCENTRATED SOLAR'S
ABOUT 13 1/2-17.

800
00:35:53,100 --> 00:35:57,300

P.V. UTILITY SCALE
IS 10-11 CENTS A KILOWATT HOUR.

801
00:35:57,300 --> 00:36:01,333
NOW, IF WE USE THE 2050 MIX

802
00:36:01,333 --> 00:36:04,833
OF WIND/WATER/SOLAR
TECHNOLOGIES THAT WE WANT

803
00:36:04,833 --> 00:36:07,200
AND APPLY THEM
TO THESE COSTS,

804
00:36:07,200 --> 00:36:12,166
THEN WE GET ABOUT 11.3 CENTS
A KILOWATT HOUR ON AVERAGE.

805
00:36:12,166 --> 00:36:14,166
AND THAT COMPARES TO
CONVENTIONAL FUELS RIGHT NOW

806
00:36:14,166 --> 00:36:15,633
AT 10 CENTS A KILOWATT HOUR.

807
00:36:15,633 --> 00:36:19,566
BUT THERE'S ANOTHER 5 CENTS
A KILOWATT HOUR OF EXTERNALITY,

808
00:36:19,566 --> 00:36:21,500
OR HEALTH AND CLIMATE COSTS
ASSOCIATED WITH THAT.

809
00:36:21,500 --> 00:36:23,100
SO THEY'RE REALLY 15 CENTS
A KILOWATT HOUR,

810
00:36:23,100 --> 00:36:25,233
ALTHOUGH THE...

811
00:36:25,233 --> 00:36:28,500
THESE UTILITIES
AND THE ENERGY COMPANIES

812
00:36:28,500 --> 00:36:31,600
ARE GETTING A FREE RIDE
FOR 5 CENTS A KILOWATT HOUR.

813
00:36:31,600 --> 00:36:34,433
SO RIGHT NOW, PEOPLE CAN ARGUE
THAT WIND/WATER/SOLAR

814
00:36:34,433 --> 00:36:36,500
IS MORE EXPENSIVE
IF WE CONVERTED EVERYTHING.

815
00:36:36,500 --> 00:36:39,433
EXCEPT WIND, ONSHORE WIND,
GEOTHERMAL AND HYDRO

816
00:36:39,433 --> 00:36:40,700
ARE COST-COMPETITIVE.

817
00:36:40,700 --> 00:36:42,866
IN FACT, ONSHORE WIND
IS THE CHEAPEST FORM

818
00:36:42,866 --> 00:36:45,000
OF NEW ELECTRIC POWER
IN THE U.S. RIGHT NOW,

819
00:36:45,000 --> 00:36:46,633
IN THE GREAT PLAINS.

820
00:36:46,633 --> 00:36:48,733
IT'S ON THE ORDER OF 2 CENTS
A KILOWATT HOUR SUBSIDIZED,

821
00:36:48,733 --> 00:36:50,700

AND 3 1/2 CENTS UNSUBSIDIZED.

822
00:36:50,700 --> 00:36:52,133
AND THAT'S LESS
THAN NATURAL GAS.

823
00:36:52,133 --> 00:36:53,800
BUT IF WE GO TO 2030,

824
00:36:53,800 --> 00:36:56,200
BECAUSE YOU STABILIZED
THE ENERGY PRICES

825
00:36:56,200 --> 00:36:57,800
WITH WIND/WATER/SOLAR,

826
00:36:57,800 --> 00:36:59,033
BECAUSE THEY HAVE ZERO
FUEL COSTS.

827
00:36:59,033 --> 00:37:00,466
SO THEIR COSTS
ARE ALL GOING DOWN,

828
00:37:00,466 --> 00:37:02,400
WHEREAS FOSSIL FUELS,
IF YOU JUST LOOK AT THE TREND

829
00:37:02,400 --> 00:37:03,900
FOR THE LAST TEN YEARS,

830
00:37:03,900 --> 00:37:05,333
AND YOU JUST PROJECT FORWARD,

831
00:37:05,333 --> 00:37:07,333
YOU'RE GOING TO GET 17 CENTS
A KILOWATT HOUR

832
00:37:07,333 --> 00:37:09,733

FOR FOSSIL FUELS IN 2030,

833
00:37:09,733 --> 00:37:11,666
PLUS ANOTHER 6 CENTS
FOR EXTERNALITY.

834
00:37:11,666 --> 00:37:13,433
SO THAT'S 23 CENTS
A KILOWATT HOUR.

835
00:37:13,433 --> 00:37:18,266
SO IN 2050, WIND/WATER/SOLAR
WILL BE, ON THE AVERAGE,

836
00:37:18,266 --> 00:37:21,466
6 CENTS A KILOWATT HOUR
VERSUS 17 CENTS A KILOWATT HOUR

837
00:37:21,466 --> 00:37:23,066
FOR THE FOSSIL FUELS.

838
00:37:23,066 --> 00:37:26,066
AND TO JUST
DEMONSTRATE HOW--

839
00:37:26,066 --> 00:37:28,333
WE'LL LOOK AT SOME OF THESE
COST BENEFITS IN A SECOND,

840
00:37:28,333 --> 00:37:29,866
BUT I WANT TO DEMONSTRATE
HOW YOU STABILIZE PRICES

841
00:37:29,866 --> 00:37:31,466
IN A SECOND.

842
00:37:31,466 --> 00:37:35,333
BUT THE ADDITIONAL BENEFIT,
THE EXTERNALITY BENEFIT

843
00:37:35,333 --> 00:37:38,933
OF ELIMINATING FOSSIL FUELS
WITH WIND/WATER/SOLAR

844
00:37:38,933 --> 00:37:43,700
IS--IS IN REDUCING AIR POLLUTION
HEALTH COSTS AND CLIMATE COSTS.

845
00:37:43,700 --> 00:37:45,900
AS I MENTIONED EARLIER,
THERE ARE 63,000 PEOPLE

846
00:37:45,900 --> 00:37:47,500
DIE PREMATURELY EACH YEAR.

847
00:37:47,500 --> 00:37:51,833
AND THAT COSTS ABOUT
$510 BILLION TO THE U.S.,

848
00:37:51,833 --> 00:37:53,966
OR 3.2% OF ITS G.D.P.

849
00:37:53,966 --> 00:37:57,000
GLOBAL WARMING COSTS
TO THE WORLD FROM U.S. EMISSIONS

850
00:37:57,000 --> 00:37:59,966
ARE ABOUT $730 BILLION
BY 2050.

851
00:37:59,966 --> 00:38:02,966
SO THESE COSTS
WOULD BE ELIMINATED.

852
00:38:02,966 --> 00:38:05,700
BUT THE COSTS CHANGE.

853
00:38:05,700 --> 00:38:08,033
JUST TO DEMONSTRATE

THAT YOU STABILIZE

854
00:38:08,033 --> 00:38:09,833
THE ACTUAL DIRECT COST
OF ENERGY,

855
00:38:09,833 --> 00:38:14,166
IF YOU LOOK AT THE 11 STATES
IN THE U.S. WITH THE MOST--

856
00:38:14,166 --> 00:38:16,566
THE HIGHEST FRACTION
OF ELECTRICITY FROM WIND,

857
00:38:16,566 --> 00:38:19,533
IN THE TOP TWO
ARE IOWA AND SOUTH DAKOTA,

858
00:38:19,533 --> 00:38:23,866
WITH ABOUT 28% OF ALL
ELECTRICITY FROM WIND LAST YEAR.

859
00:38:23,866 --> 00:38:25,133
THEIR--THEIR STATES,

860
00:38:25,133 --> 00:38:26,566
THE 11 STATES WITH
THE HIGHEST FRACTION

861
00:38:26,566 --> 00:38:31,533
OF ELECTRIC POWER FROM WIND
HAVE DECREASED IN COST .4%

862
00:38:31,533 --> 00:38:32,766
IN THE LAST FIVE YEARS.

863
00:38:32,766 --> 00:38:34,500
ALL THE OTHER STATES
WENT UP 8%,

864
00:38:34,500 --> 00:38:36,200
BECAUSE WIND HAS ZERO
FUEL COSTS.

865
00:38:36,200 --> 00:38:38,033
SO IT'S ALL
IN CAPITAL COSTS.

866
00:38:38,033 --> 00:38:39,833
IT HAS HIGHER CAPITAL COSTS
THAN FOSSIL FUELS,

867
00:38:39,833 --> 00:38:41,133
BUT LOWER FUEL COSTS.

868
00:38:41,133 --> 00:38:43,666
SO YOU KNOW
WHAT THE COST WILL BE.

869
00:38:43,666 --> 00:38:45,500
IT'LL STAY STABLE OVER TIME,

870
00:38:45,500 --> 00:38:48,466
WHEREAS FOSSIL FUEL COSTS GO UP
OVER TIME.

871
00:38:48,466 --> 00:38:49,933
IN TERMS OF JOBS,

872
00:38:49,933 --> 00:38:53,766
WE LOOKED AT EACH STATE TO LOOK
AT JOB CREATION VERSUS LOST,

873
00:38:53,766 --> 00:38:56,066
AND USED THE N.R.E.L.
J.E.D.I. MODELS

874
00:38:56,066 --> 00:38:58,033
TO DETERMINE JOB CREATION.

875
00:38:58,033 --> 00:39:01,133
AND LOOKED AT ACTUAL JOBS
THAT WOULD BE LOST

876
00:39:01,133 --> 00:39:03,266
IN FOSSIL FUEL INDUSTRIES.

877
00:39:03,266 --> 00:39:05,766
WE FOUND 5 MILLION
40-YEAR CONSTRUCTION JOBS

878
00:39:05,766 --> 00:39:07,066
WOULD BE CREATED,

879
00:39:07,066 --> 00:39:10,400
AND ANOTHER 2.4 MILLION
OPERATION JOBS.

880
00:39:10,400 --> 00:39:13,433
SO IT'S ABOUT 7 1/2 MILLION JOBS
CREATED

881
00:39:13,433 --> 00:39:16,666
VERSUS 3.9 MILLION JOBS IN THE
FOSSIL AND NUCLEAR INDUSTRIES,

882
00:39:16,666 --> 00:39:18,833
WHICH WOULD BE LOST
IF WE DO THIS CONVERGENT.

883
00:39:18,833 --> 00:39:22,233
SO THERE WOULD
BE A NET JOB GAIN.

884
00:39:22,233 --> 00:39:23,733
AND THEN ONE MORE POINT
I WANT TO MAKE

885

00:39:23,733 --> 00:39:26,600
IS ABOUT MATCHING
POWER SUPPLY WITH DEMAND.

886
00:39:26,600 --> 00:39:27,933
PEOPLE SAY THE WIND
DOESN'T ALWAYS BLOW,

887
00:39:27,933 --> 00:39:29,433
THE SUN DOESN'T ALWAYS SHINE.

888
00:39:29,433 --> 00:39:32,133
WELL, CAN YOU MAKE IT RELIABLE?

889
00:39:32,133 --> 00:39:34,366
WE DID A STUDY
A FEW YEARS AGO

890
00:39:34,366 --> 00:39:37,833
LOOKING AT CALIFORNIA.

891
00:39:37,833 --> 00:39:42,833
AND USING CALIFORNIA DEMAND
FOR 2006 AND '05,

892
00:39:42,833 --> 00:39:46,133
AND THAT'S THE BLACK LINE
IN EACH OF THESE PLOTS.

893
00:39:46,133 --> 00:39:48,433
AND THESE ARE TWO
PARTICULAR DAYS.

894
00:39:48,433 --> 00:39:50,900
AND THEN TAKING THAT DEMAND
AND SEE IF WE CAN MATCH IT

895
00:39:50,900 --> 00:39:53,866
WITH EXISTING GEOTHERMAL
EXISTING HYDRO,

896
00:39:53,866 --> 00:39:55,966
BUT JUST INCREASING
WIND AND SOLAR.

897
00:39:55,966 --> 00:39:59,900
SO THE LIGHT BLUE
ON THESE GRAPHS ARE WIND.

898
00:39:59,900 --> 00:40:01,866
AND THAT'S USING WIND DATA

899
00:40:01,866 --> 00:40:04,866
GIVEN SEVERAL LOCATIONS
IN CALIFORNIA.

900
00:40:04,866 --> 00:40:06,966
THE YELLOW IS SOLAR P.V.

901
00:40:06,966 --> 00:40:09,466
THE ORANGE IS CONCENTRATED
SOLAR POWER.

902
00:40:09,466 --> 00:40:10,866
AND THE BLUE
IS HYDROELECTRIC,

903
00:40:10,866 --> 00:40:12,500
WHICH IS USED
TO FILL IN THE GAPS.

904
00:40:12,500 --> 00:40:15,733
AND YOU CAN SEE--AND THEN THE
RED IS GEOTHERMAL AT THE BOTTOM.

905
00:40:15,733 --> 00:40:17,733
YOU CAN SEE ON THESE TWO
PARTICULAR DAYS

906

00:40:17,733 --> 00:40:22,233
WE CAN MATCH THE POWER DEMAND,
THE BLACK LINE, EXACTLY.

907
00:40:22,233 --> 00:40:23,800
THE GRAY ABOVE THE BLACK LINE

908
00:40:23,800 --> 00:40:26,066
IS SPINNING RESERVES
OF NATURAL GAS,

909
00:40:26,066 --> 00:40:28,366
WHICH WAS NEVER USED
ON THESE TWO DAYS.

910
00:40:28,366 --> 00:40:31,100
IN FACT, WE FOUND THAT THE
NATURAL GAS WAS NEVER NEEDED

911
00:40:31,100 --> 00:40:34,600
EXCEPT FOR 0.2% OF THE HOURS
OVER TWO YEARS.

912
00:40:34,600 --> 00:40:37,166
SO WE CAN MATCH IT EVERY HOUR
OF EVERY DAY

913
00:40:37,166 --> 00:40:39,200
WITH JUST WIND/WATER/SOLAR
TECHNOLOGIES.

914
00:40:39,200 --> 00:40:42,066
AND THIS WAS WITHOUT
EVEN DOING THINGS

915
00:40:42,066 --> 00:40:43,966
LIKE DEMAND RESPONSE
MANAGEMENT,

916
00:40:43,966 --> 00:40:47,033

OVERSIZING THE GRID
WITH RENEWABLES

917
00:40:47,033 --> 00:40:48,533
TO MAKE IT EASIER
TO MATCH DEMAND,

918
00:40:48,533 --> 00:40:50,133
AND THEN USING
THE EXCESS ELECTRICITY

919
00:40:50,133 --> 00:40:51,933
FOR PRODUCING HYDROGEN.

920
00:40:51,933 --> 00:40:56,066
OR USING VERY MUCH CONCENTRATED
SOLAR POWER WITH STORAGE.

921
00:40:56,066 --> 00:40:58,266
SO ANYWAY, WE THINK IT'S MORE
OF AN OPTIMIZATION PROBLEM

922
00:40:58,266 --> 00:40:59,800
TO MATCH THE POWER DEMAND.

923
00:40:59,800 --> 00:41:01,966
AND THEN FINALLY,
I JUST WANT TO SHOW

924
00:41:01,966 --> 00:41:04,866
WHAT'S THE TIMELINE
FOR THE TRANSITION.

925
00:41:04,866 --> 00:41:09,600
IF WE LOOK FROM 2010 TO 2050--
WELL, IF WE DON'T DO ANYTHING,

926
00:41:09,600 --> 00:41:14,300
WE GO FROM 2.4 TERAWATTS
OF U.S. POWER DEMAND IN 2010

927
00:41:14,300 --> 00:41:16,533
TO 3.1 TERAWATTS.

928
00:41:16,533 --> 00:41:19,700
THAT'S THE TOP--
THE TOP LINE,

929
00:41:19,700 --> 00:41:21,466
WHICH IS THE BUSINESS-AS-USUAL
LINE.

930
00:41:21,466 --> 00:41:24,433
IF WE JUST CONVERT EVERYTHING
TO ELECTRICITY

931
00:41:24,433 --> 00:41:26,133
PLUS ELECTROLYTIC HYDROGEN,

932
00:41:26,133 --> 00:41:29,233
THEN WE GET ABOUT--

933
00:41:29,233 --> 00:41:31,700
UH, WE GO DOWN
TO THE SECOND LINE,

934
00:41:31,700 --> 00:41:34,133
WHICH IS THE REDUCTION
OF POWER DEMAND

935
00:41:34,133 --> 00:41:35,966
BY ONE TERAWATT
IN THE U.S.

936
00:41:35,966 --> 00:41:37,900
JUST DUE TO THE EFFICIENCY
OF ELECTRICITY.

937
00:41:37,900 --> 00:41:40,100

THEN WE CAN REDUCE IT
ANOTHER .2 TERAWATTS,

938
00:41:40,100 --> 00:41:41,600
OR PROBABLY EVEN MORE

939
00:41:41,600 --> 00:41:43,766
JUST WITH END-USE ENERGY
EFFICIENCY IMPROVEMENTS

940
00:41:43,766 --> 00:41:45,466
TO GET TO THE 100% LINE.

941
00:41:45,466 --> 00:41:49,166
AND ALL THE REST OF THAT WOULD
BE WIND/WATER/SOLAR PRODUCED.

942
00:41:49,166 --> 00:41:51,966
AND WE EXPECT THAT BY 2020,

943
00:41:51,966 --> 00:41:54,933
IF WE CAN GET ALL NEW ENERGY
TO BE CLEAN--

944
00:41:54,933 --> 00:41:57,166
SO ALL NEW CARS,
ELECTRIC CARS,

945
00:41:57,166 --> 00:42:00,700
ALL NEW ELECTRICITY,
WIND/WATER/SOLAR ELECTRICITY,

946
00:42:00,700 --> 00:42:05,666
AND THEN REPLACE EXISTING
INFRASTRUCTURE AS IT RETIRES

947
00:42:05,666 --> 00:42:07,033
WITH CLEAN ENERGY,

948

00:42:07,033 --> 00:42:08,733
AND THEN HAVE AGGRESSIVE
POLICY MEASURES,

949
00:42:08,733 --> 00:42:11,666
BY 2030 WE'D HAVE REPLACED
80% OF THE INFRASTRUCTURE

950
00:42:11,666 --> 00:42:13,066
TO 80-85%.

951
00:42:13,066 --> 00:42:15,200
AND BY 2050, 100%.

952
00:42:15,200 --> 00:42:17,400
AND WE WOULD HAVE ELIMINATED
ALL THESE PROBLEMS.

953
00:42:17,400 --> 00:42:21,333
SO THE OVERALL SUMMARY
IS HERE.

954
00:42:21,333 --> 00:42:23,366
IF WE CONVERT EVERYTHING
TO WIND/WATER/SOLAR

955
00:42:23,366 --> 00:42:25,400
AND ELECTRICITY HYDROGEN
IN THE U.S.,

956
00:42:25,400 --> 00:42:29,233
WE'D REDUCE POWER DEMAND
BY OVER 37%.

957
00:42:29,233 --> 00:42:32,133
ACTUALLY, YOU KNOW,
LET'S CLOSE IT UP.

958
00:42:32,133 --> 00:42:35,533
ELIMINATE 63,000 U.S.

AIR POLLUTION DEATHS

959
00:42:35,533 --> 00:42:39,166
AND $730 BILLION IN GLOBAL
CLIMATE COSTS,

960
00:42:39,166 --> 00:42:41,833
CREATE 5 MILLION
40-YEAR CONSTRUCTION JOBS,

961
00:42:41,833 --> 00:42:44,433
2.4 MILLION 40-YEAR
OPERATION JOBS,

962
00:42:44,433 --> 00:42:47,433
COST 3.9 MILLION FOSSIL FUEL
AND NUCLEAR JOB,

963
00:42:47,433 --> 00:42:52,200
SAVE ABOUT $4,400 PER YEAR PER
PERSON IN DIRECT ENERGY COSTS

964
00:42:52,200 --> 00:42:54,433
JUST BY LOOKING AT THE PRICE
DIFFERENTIAL

965
00:42:54,433 --> 00:42:57,533
IF WE GO BUSINESS AS USUAL
VERSUS WIND/WATER/SOLAR,

966
00:42:57,533 --> 00:42:58,833
LOOKING AT THE TRENDS.

967
00:42:58,833 --> 00:43:01,100
AND ANOTHER $3,100 PER YEAR
PER PERSON

968
00:43:01,100 --> 00:43:03,500
IN HEALTH AND CLIMATE COSTS
IN 2050.

969
00:43:03,500 --> 00:43:07,200
WE'D REQUIRE ONLY .44% OF THE
U.S. LAND AREA FOR FOOTPRINT,

970
00:43:07,200 --> 00:43:09,700
AND 1.7% FOR SPACING.

971
00:43:09,700 --> 00:43:12,733
THERE ARE SEVERAL METHODS
OF ADDRESSING THE VARIABILITY

972
00:43:12,733 --> 00:43:14,766
OF WIND/WATER/SOLAR
TECHNOLOGIES.

973
00:43:14,766 --> 00:43:16,300
WE DIDN'T FIND
MATERIAL LIMITS,

974
00:43:16,300 --> 00:43:18,833
BUT RECYCLING MAY BE NEEDED
FOR SOME COMPONENTS.

975
00:43:18,833 --> 00:43:21,300
THE BARRIERS ARE PRIMARILY
UP-FRONT COSTS,

976
00:43:21,300 --> 00:43:23,166
BECAUSE IT'S VERY
CAPITAL-INTENSIVE.

977
00:43:23,166 --> 00:43:25,333
TRANSMISSION NEEDS ARE...

978
00:43:25,333 --> 00:43:27,466
THEY'RE NOT A TECHNICAL
OR ECONOMIC BARRIER,

979

00:43:27,466 --> 00:43:28,866
BUT MORE SOCIAL
AND POLITICAL BARRIER.

980
00:43:28,866 --> 00:43:31,100
BUT THEN LOBBYING
AND POLITICS

981
00:43:31,100 --> 00:43:34,633
IS THE MAIN BARRIER.

982
00:43:34,633 --> 00:43:36,866
AND JUST FINALLY,
IF YOU WANT MORE INFORMATION,

983
00:43:36,866 --> 00:43:38,966
THERE ARE A COUPLE
OF WEBSITES HERE

984
00:43:38,966 --> 00:43:43,700
THAT HAVE ALL THE PAPERS
ASSOCIATED WITH THESE PLANS.

985
00:43:43,700 --> 00:43:47,366
AND YOU MIGHT BE INTERESTED
IN THE SOLUTIONS PROJECT,

986
00:43:47,366 --> 00:43:48,633
WHICH IS A GROUP
THAT'S DEDICATED

987
00:43:48,633 --> 00:43:50,566
TO TAKING THESE
SCIENCE-BASED PLANS

988
00:43:50,566 --> 00:43:52,233
AND TRYING TO IMPLEMENT THEM

989
00:43:52,233 --> 00:43:56,033
AT THE STATE AND COUNTRY

AND WORLD LEVELS,

990
00:43:56,033 --> 00:44:00,633
AND TRYING TO INVOLVE
BUSINESSES, AND...

991
00:44:00,633 --> 00:44:02,600
AND BUSINESS AND CULTURE

992
00:44:02,600 --> 00:44:05,666
AND ALONG WITH THE SCIENCE
AND TECHNOLOGY.

993
00:44:05,666 --> 00:44:07,600
SO ANYWAY,
THANK YOU VERY MUCH,

994
00:44:07,600 --> 00:44:08,966
AND I'LL WELCOME--

995
00:44:08,966 --> 00:44:10,433
I'M HAPPY TO TAKE
ANY QUESTIONS YOU HAVE.

996
00:44:10,433 --> 00:44:12,433
THANKS.
[applause]

997
00:44:14,533 --> 00:44:16,666
THANK YOU VERY MUCH.

998
00:44:18,766 --> 00:44:20,900
- SO, WE HAVE TIME
FOR A FEW QUESTIONS.

999
00:44:20,900 --> 00:44:23,900
PLEASE RAISE YOUR HAND,
WAIT FOR THE MICROPHONE,

1000

00:44:23,900 --> 00:44:26,700
AND STAND UP WHEN YOU GET
THE MICROPHONE.

1001
00:44:32,666 --> 00:44:35,400
- I REMEMBER READING THIS
IN THE "SCIENTIFIC AMERICAN"

1002
00:44:35,400 --> 00:44:37,100
A FEW YEARS AGO,

1003
00:44:37,100 --> 00:44:40,200
AND THE COMMENTS WERE
PRETTY BRUTAL FOR THAT ARTICLE,

1004
00:44:40,200 --> 00:44:43,433
CRITICIZING IT FOR NOT TAKING
INTO ACCOUNT THE SUNK COSTS

1005
00:44:43,433 --> 00:44:45,266
OF THE PIPES IN THE GROUND

1006
00:44:45,266 --> 00:44:47,666
FOR THE TRADITIONAL
OIL INFRASTRUCTURE.

1007
00:44:47,666 --> 00:44:51,600
I WONDER WHAT YOUR RESPONSE WAS
TO THAT.

1008
00:44:51,600 --> 00:44:54,433
- THE SUNK COST--
WELL, THERE IS A SUNK INFRA--

1009
00:44:54,433 --> 00:44:56,833
BUT, SO WE'RE GOING
TO BE REPLACING--

1010
00:44:56,833 --> 00:44:59,600
WHEN WE HAVE NEW ENERGY DEMAND

WE'D BE REPLACING

1011
00:44:59,600 --> 00:45:01,166
WITH WIND/WATER/SOLAR.

1012
00:45:01,166 --> 00:45:04,433
WHEN EXISTING PLANTS RETIRE,

1013
00:45:04,433 --> 00:45:06,366
THEN WE'D BE REPLACING--

1014
00:45:06,366 --> 00:45:08,600
INSTEAD OF BUILDING
A NEW COAL PLANT,

1015
00:45:08,600 --> 00:45:12,700
WE'RE GOING TO BUILD A NEW,
A SOLAR FARM OR SOMETHING.

1016
00:45:12,700 --> 00:45:15,833
SO WE'RE RELYING
ON NATURAL RETIREMENTS

1017
00:45:15,833 --> 00:45:18,200
AS WELL AS SOME FORCED
RETIREMENTS.

1018
00:45:18,200 --> 00:45:20,933
SO COAL PLANTS ARE COMING
OUT OF THE GROUND.

1019
00:45:20,933 --> 00:45:23,066
BUT THOSE SUNK COSTS
ARE PRETTY TRIVIAL

1020
00:45:23,066 --> 00:45:25,500
COMPARED TO THE HEALTH
AND CLIMATE COSTS

1021

00:45:25,500 --> 00:45:27,900
THAT THOSE PLANTS
ARE CAUSING.

1022
00:45:27,900 --> 00:45:29,066
SO I WOULD--

1023
00:45:29,066 --> 00:45:30,533
YEAH, BUT WE'RE BASICALLY--

1024
00:45:30,533 --> 00:45:32,033
THERE'S GOING TO BE
NATURAL RETIREMENTS.

1025
00:45:32,033 --> 00:45:33,400
I MEAN, JUST TO PUT IT
IN PERSPECTIVE.

1026
00:45:33,400 --> 00:45:35,233
IF WE DID THIS WORLDWIDE,

1027
00:45:35,233 --> 00:45:37,833
WE'D HAVE TO SPEND $100 TRILLION
IN CAPITAL COSTS

1028
00:45:37,833 --> 00:45:39,333
TO REPLACE EVERYTHING.

1029
00:45:39,333 --> 00:45:41,866
BUT THE FOSSIL FUEL INDUSTRY
SPENDS--

1030
00:45:41,866 --> 00:45:44,833
I THINK THE NUMBER
WAS $6-7 TRILLION A YEAR.

1031
00:45:44,833 --> 00:45:49,300
SO IT WOULD BASICALLY PAY--
YOU KNOW, PAY FOR THEIR SYSTEM.

1032
00:45:49,300 --> 00:45:52,100
AND, YOU KNOW,
YOU CAN COUNT THE YEARS.

1033
00:45:52,100 --> 00:45:54,466
TEN, FIFTEEN YEARS OR SO.

1034
00:45:59,700 --> 00:46:02,466
- RIGHT NOW WE DON'T USE
A LOT OF HYDROGEN,

1035
00:46:02,466 --> 00:46:04,133
BUT WE DO USE SOME.

1036
00:46:04,133 --> 00:46:08,100
AND WE HAVE EXCESS ELECTRICITY
AT CERTAIN HOURS OF THE DAY

1037
00:46:08,100 --> 00:46:09,433
IN CERTAIN AREAS.

1038
00:46:09,433 --> 00:46:11,366
WHY ISN'T THAT,

1039
00:46:11,366 --> 00:46:14,300
ELECTROLYSIS
WITH THE ELECTRICITY,

1040
00:46:14,300 --> 00:46:17,500
THE PRIMARY SOURCE
OF HYDROGEN?

1041
00:46:17,500 --> 00:46:18,933
- EXACTLY. WELL, THAT'S PART
OF THIS PLAN.

1042
00:46:18,933 --> 00:46:20,866
YOU WOULD,
INSTEAD OF CURTAILING--

1043
00:46:20,866 --> 00:46:23,133
BECAUSE RIGHT NOW WHEN WE HAVE
TOO MUCH WIND

1044
00:46:23,133 --> 00:46:25,066
OR TOO MUCH SOLAR
IN THE U.S.

1045
00:46:25,066 --> 00:46:27,766
A LOT OF TIMES IT JUST
GETS WASTED. IT'S NOT USED.

1046
00:46:27,766 --> 00:46:30,766
AND--BUT IN DENMARK,
THEY USE EXTRA WIND

1047
00:46:30,766 --> 00:46:32,100
FOR DISTRICT HEATING.

1048
00:46:32,100 --> 00:46:33,466
SO THEY USE IT
TO HEAT THE CITIES.

1049
00:46:33,466 --> 00:46:36,933
AND ANOTHER PLAN WAS TO USE IT
TO PRODUCE HYDROGEN

1050
00:46:36,933 --> 00:46:39,233
BY ELECTROLYSIS,
SO YOU CAN THEN STORE IT.

1051
00:46:39,233 --> 00:46:40,533
OR SOME OTHER STORAGE.

1052
00:46:40,533 --> 00:46:41,966
OR YOU CAN USE IT
FOR PUMPED HYDRO.

1053

00:46:41,966 --> 00:46:43,933
ACTUALLY, LIKE,
A THIRD OF ALL THE--

1054
00:46:43,933 --> 00:46:47,700
THE HYDROELECTRIC POWER
IN CALIFORNIA IS PUMPED HYDRO.

1055
00:46:47,700 --> 00:46:50,533
SO YOU CAN ACTUALLY JUST PUMP IT
UP TO A HIGHER RESERVOIR.

1056
00:46:50,533 --> 00:46:52,000
WHEN YOU HAVE EXTRA
ELECTRICITY.

1057
00:46:52,000 --> 00:46:53,733
SO THERE'S NO REASON AT ALL
THAT YOU CAN'T DO IT.

1058
00:46:53,733 --> 00:46:55,166
IT JUST HASN'T
BEEN DONE A LOT.

1059
00:46:55,166 --> 00:46:56,533
AND THAT'S--AS PART
OF THIS PLAN.

1060
00:46:56,533 --> 00:46:58,166
THAT WOULD BE ONE OF THE GOALS

1061
00:46:58,166 --> 00:47:01,766
WOULD NOT BE TO CURTAIL
ANY WIND OR SOLAR.

1062
00:47:02,800 --> 00:47:04,566
- STAND UP.

1063
00:47:04,566 --> 00:47:06,300
- I WAS WONDERING

IF YOU CAN TALK ABOUT

1064
00:47:06,300 --> 00:47:08,366
HOW MUCH ENERGY STORAGE
IS NEEDED?

1065
00:47:08,366 --> 00:47:10,333
FROM ONE OF YOUR SLIDES
ABOUT DEMAND-RESPONSE,

1066
00:47:10,333 --> 00:47:11,900
IT SOUNDED LIKE
YOU WERE SAYING

1067
00:47:11,900 --> 00:47:13,600
THAT IT COULD BE MANAGED
IN REAL TIME.

1068
00:47:13,600 --> 00:47:17,966
BUT RATHER--IN ADDITION
TO A GENERATION BEING RANDOM,

1069
00:47:17,966 --> 00:47:19,400
OR AT DIFFERENT CYCLES,

1070
00:47:19,400 --> 00:47:21,433
THE ENERGY USAGE IS ALSO
IN DIFFERENT CYCLES AS WELL.

1071
00:47:21,433 --> 00:47:24,133
I WAS WONDERING HOW THAT
ALL COMES TOGETHER.

1072
00:47:24,133 --> 00:47:27,166
- WELL, CERTAINLY THE MORE
STORAGE WE HAVE, THE BETTER.

1073
00:47:27,166 --> 00:47:30,400
THE STUDY THAT I SHOWED YOU
INDICATED THAT, YOU KNOW,

1074
00:47:30,400 --> 00:47:31,866
IF PUSH CAME TO SHOVE

1075
00:47:31,866 --> 00:47:33,566
WE COULD GET AWAY WITH
NOT A WHOLE LOT OF IT.

1076
00:47:33,566 --> 00:47:35,600
BUT THE MORE WE HAVE,
THE BETTER.

1077
00:47:35,600 --> 00:47:37,233
IN THESE PLANS,
I MEAN, THERE'S--

1078
00:47:37,233 --> 00:47:39,266
HYDROELECTRIC IS A FORM
OF STORAGE ALREADY.

1079
00:47:39,266 --> 00:47:42,766
AND CONCENTRATED SOLAR POWER
WITH STORAGE

1080
00:47:42,766 --> 00:47:45,066
IF A FORM OF STORAGE
THAT WE ACCOUNTED FOR.

1081
00:47:45,066 --> 00:47:47,166
UM, AND SO THOSE ARE TWO FORMS
OF STORAGE.

1082
00:47:47,166 --> 00:47:48,866
BUT THERE ARE ADDITIONAL
FORMS OF STORAGE

1083
00:47:48,866 --> 00:47:50,900
COULD BE LIKE IN HYDROGEN.

1084

00:47:50,900 --> 00:47:54,466
IT COULD BE IN BATTERIES
OR IT COULD BE IN FLYWHEELS.

1085
00:47:54,466 --> 00:47:56,600
COULD BE SOIL IN SOIL.

1086
00:47:56,600 --> 00:47:58,400
LIKE, THERE'S A TOWN IN CANADA

1087
00:47:58,400 --> 00:48:01,500
THAT--THAT HEATS THE SOIL
IN THE SUMMER

1088
00:48:01,500 --> 00:48:03,200
AND THEN USES THAT HEAT
IN THE WINTER

1089
00:48:03,200 --> 00:48:05,300
TO POWER 90%
OF THEIR HEATING.

1090
00:48:05,300 --> 00:48:06,900
SO THE MORE,
THE BETTER.

1091
00:48:06,900 --> 00:48:09,066
BUT THERE'S A--OUR STUDY
AND ANOTHER STUDY SHOW

1092
00:48:09,066 --> 00:48:13,933
THAT YOU CAN DO, LIKE,
98-99% OF THE GRID RELIABLY

1093
00:48:13,933 --> 00:48:15,433
WITHOUT A WHOLE LOT OF STORAGE,

1094
00:48:15,433 --> 00:48:17,466
EXCEPT FOR HYDRO
AND CONCENTRATED SOLAR POWER.

1095
00:48:17,466 --> 00:48:19,666
- OKAY. UM...

1096
00:48:19,666 --> 00:48:21,766
- I HAVE A QUESTION
BACK HERE.

1097
00:48:21,766 --> 00:48:24,166
I WAS INTERESTED
IN THIS QUESTION

1098
00:48:24,166 --> 00:48:26,100
FOR THE LAST
SIX OR SEVEN YEARS,

1099
00:48:26,100 --> 00:48:29,666
AND LOOKED AT THE PROBLEM
OF ENERGY DENSITY

1100
00:48:29,666 --> 00:48:31,966
WITH REGARD TO MOSTLY
FLYING AIRPLANES.

1101
00:48:31,966 --> 00:48:35,833
AND THE ISSUE WITH REGARD
TO LIQUID FUELS VS. HYDROGEN.

1102
00:48:35,833 --> 00:48:39,800
I LOOKED AT ALGAE AS BEING
A HUNDRED TIMES BETTER PRODUCER

1103
00:48:39,800 --> 00:48:43,733
OF HYDROCARBON LIGHT FUELS,
DIESEL,

1104
00:48:43,733 --> 00:48:46,400
BUT ALSO OTHER FUELS
THROUGH SYNGAS.

1105
00:48:46,400 --> 00:48:48,333
AND IT LOOKED LIKE
ALGAE WOULD WORK,

1106
00:48:48,333 --> 00:48:51,033
PROVIDED YOU DID IT OFFSHORE
AND DIDN'T USE LAND,

1107
00:48:51,033 --> 00:48:54,600
AND USED WASTE WATER
INSTEAD OF WATER AND FERTILIZER.

1108
00:48:54,600 --> 00:48:56,033
I DON'T KNOW IF YOU'RE FAMILIAR
WITH THE PROJECT.

1109
00:48:56,033 --> 00:49:00,600
IT WAS FUNDED AT $10 MILLION
BY N.A.S.A. FOR THREE YEARS.

1110
00:49:00,600 --> 00:49:03,100
AND WE SAW THAT ALGAE WOULD
REALLY REPLACE

1111
00:49:03,100 --> 00:49:04,633
A BIG CHUNK OF OUR LIQUID FUELS.

1112
00:49:04,633 --> 00:49:09,633
BUT WITH REGARD TO FLYING
AIRPLANES WITH YOUR SYSTEM,

1113
00:49:09,633 --> 00:49:12,166
IS IT HYDROGEN-BASED?
IS THAT YOUR PLAN?

1114
00:49:12,166 --> 00:49:15,033
- WELL, THE CRYOGENIC HYDROGEN,
WHICH WOULD BE--

1115

00:49:15,033 --> 00:49:16,600
SO, YOU DO NEED AIRPLANES,

1116
00:49:16,600 --> 00:49:18,766
AIRCRAFT THAT HAVE
LARGER VOLUME,

1117
00:49:18,766 --> 00:49:21,466
BECAUSE HUNDREDS IS NOT
VERY DENSE.

1118
00:49:21,466 --> 00:49:23,266
SO YOU NEED MORE VOLUME.
BUT IT'S LESS MASSIVE.

1119
00:49:23,266 --> 00:49:26,133
SO THERE HAVE BEEN STUDIES
IN THE U.S. AND IN EUROPE

1120
00:49:26,133 --> 00:49:28,766
SHOWING THAT THE TOTAL DRAG
ON THE AIRCRAFT

1121
00:49:28,766 --> 00:49:30,400
WOULD BE ABOUT THE SAME.

1122
00:49:30,400 --> 00:49:31,633
I MEAN, THE RUSSIANS
BUILT A HYDROGEN--

1123
00:49:31,633 --> 00:49:34,466
A CRYOGENIC HYDROGEN AIRCRAFT
IN THE 1980s,

1124
00:49:34,466 --> 00:49:36,600
BUT IT WASN'T ECONOMIC
AT THE TIME.

1125
00:49:36,600 --> 00:49:38,833
AND THE SPACE SHUTTLE RAN

ON CRYOGENIC HYDROGEN.

1126
00:49:38,833 --> 00:49:41,033
SO IT'S TECHNICALLY FEASIBLE.

1127
00:49:41,033 --> 00:49:43,200
I MEAN, ALL THE AIRCRAFT
COMPANIES HAVE LOOKED INTO IT.

1128
00:49:43,200 --> 00:49:45,400
THEY JUST--RIGHT NOW THEY JUST
HAVE A STATUS QUO,

1129
00:49:45,400 --> 00:49:47,133
SO THEY DON'T WANT
TO CHANGE ANYTHING.

1130
00:49:47,133 --> 00:49:50,200
BUT THERE'S NO TECHNICAL REASON
THEY CAN'T BE CHANGED.

1131
00:49:50,200 --> 00:49:51,733
IN TERMS OF ALGAE...

1132
00:49:51,733 --> 00:49:54,333
I MEAN, WE'RE LOOKING
AT AIR POLLUTION AND CLIMATE.

1133
00:49:54,333 --> 00:49:57,433
AND WHEN YOU BURN THE PRODUCTS
OF ALGAE,

1134
00:49:57,433 --> 00:49:59,633
YOU'RE JUST BURNING A FUEL
THAT CREATES--

1135
00:49:59,633 --> 00:50:02,566
YOU HAVE COMBUSTION PRODUCTS
THAT CONTAIN BLACK CARBON,

1136
00:50:02,566 --> 00:50:05,033
CARBON MONOXIDE,
HYDROCARBONS,

1137
00:50:05,033 --> 00:50:06,733
INCLUDING NOx AND OTHER THINGS.

1138
00:50:06,733 --> 00:50:08,866
SO YOU STILL HAVE A SIMILAR
AMOUNT OF POLLUTION.

1139
00:50:08,866 --> 00:50:11,200
PHOTOSYNTHESIS
IS ONLY 1% EFFICIENT.

1140
00:50:11,200 --> 00:50:13,266
SO YOU CAN TAKE--
EVEN THOUGH--

1141
00:50:13,266 --> 00:50:16,900
I MEAN...YOU CAN'T REALLY SKIMP
ON THE LAND.

1142
00:50:16,900 --> 00:50:19,533
YOU'RE EITHER GOING TO SPREAD IT
OUT OVER LOTS OF LAND,

1143
00:50:19,533 --> 00:50:21,666
OR YOU'LL BUILD THESE TOWERS,
WHICH WILL BE REALLY INEFFICIENT

1144
00:50:21,666 --> 00:50:23,233
IN TERMS OF PHOTOSYNTHESIS.

1145
00:50:23,233 --> 00:50:26,066
SO AS A RESULT,
YOU NEED ABOUT--

1146
00:50:26,066 --> 00:50:29,333

IT TAKES ABOUT 30 TIMES
MORE LAND.

1147
00:50:29,333 --> 00:50:31,400
IN FACT,
30-80 TIMES MORE LAND--

1148
00:50:31,400 --> 00:50:35,433
THE ENERGY YOU GET
FROM THE BIOFUEL

1149
00:50:35,433 --> 00:50:37,166
IS 30-80 TIMES LESS

1150
00:50:37,166 --> 00:50:41,200
THAN THAT OF PUTTING SOLAR
PHOTOVOLTAICS ON THE SAME LAND,

1151
00:50:41,200 --> 00:50:44,200
BECAUSE, YOU KNOW,
THE PHOTOVOLTAICS, YOU CAN GET--

1152
00:50:44,200 --> 00:50:46,900
THEY HAVE EFFICIENCIES
IN THE ORDER OF 20, 25%.

1153
00:50:46,900 --> 00:50:49,133
WELL, 22% AT THE MOST.

1154
00:50:49,133 --> 00:50:50,533
BUT PHOTOSYNTHESIS
IS MUCH LESS.

1155
00:50:50,533 --> 00:50:54,366
- YEAH, BUT PHOTOSYNTHESIS
CAN BE UP TO 5 OR EVEN 7%

1156
00:50:54,366 --> 00:50:57,000
AND THE SYSTEM WE DESIGNED
DOESN'T USE ANY.

1157
00:50:57,000 --> 00:50:59,166
ZERO, IT'S ALL OFFSHORE.
- OKAY.

1158
00:50:59,166 --> 00:51:01,533
I GOT IT. WELL, I'M INTERESTED
TO LOOK AT IT.

1159
00:51:01,533 --> 00:51:03,166
BUT IT STILL--IT HAS THE PROBLEM
OF COMBUSTION.

1160
00:51:03,166 --> 00:51:06,733
THAT'S STILL
THE MAIN PROBLEM.

1161
00:51:06,733 --> 00:51:09,366
- UM--OH, SORRY.

1162
00:51:09,366 --> 00:51:10,833
GO AHEAD.

1163
00:51:10,833 --> 00:51:12,400
- I'M JUST WONDERING
IF YOU'D TALK A LITTLE BIT

1164
00:51:12,400 --> 00:51:13,933
ABOUT SOLAR THERMAL ENERGY,

1165
00:51:13,933 --> 00:51:17,366
AND WHETHER OR NOT YOU THINK
THAT'S A GOOD IDEA TO INVEST IN.

1166
00:51:17,366 --> 00:51:20,566
- WELL, THERE ARE DIFFERENT
TYPES OF SOLAR THERMAL,

1167
00:51:20,566 --> 00:51:23,166

LIKE THE CONCENTRATED SOLAR
POWERS FORM A SOLAR THERMAL.

1168
00:51:23,166 --> 00:51:25,600
OR ARE YOU TALKING ABOUT
THE ROOFTOP...?

1169
00:51:25,600 --> 00:51:27,466
- I MEAN, HAVING STEAM
GENERATION

1170
00:51:27,466 --> 00:51:31,333
FROM SOLAR THERMAL, AND RUNNING
GENERATORS FROM THAT.

1171
00:51:31,333 --> 00:51:34,466
- WELL, SO CONCENTRATED SOLAR
POWER IS WHERE YOU FOCUS LIGHT

1172
00:51:34,466 --> 00:51:37,066
ONTO MIRRORS,
ONTO ESSENTIAL TOWER RECEIVER,

1173
00:51:37,066 --> 00:51:39,666
TO HEAT A FLUID
SUCH A MOLTEN NITRATE SALT.

1174
00:51:39,666 --> 00:51:42,866
AND THEN YOU CAN STORE THAT
MOLTEN NITRATE SALT OVERNIGHT,

1175
00:51:42,866 --> 00:51:46,133
AND THEN USE IT TO RUN IT
NEXT TO WATER

1176
00:51:46,133 --> 00:51:47,366
TO EVAPORATE THE WATER

1177
00:51:47,366 --> 00:51:49,266
TO GENERATE THE STEAM

FOR A STEAM TURBINE.

1178
00:51:49,266 --> 00:51:51,466
AND THAT'S GREAT.
SO THAT'S--

1179
00:51:51,466 --> 00:51:52,766
IT'S A LITTLE MORE COSTLY
RIGHT NOW,

1180
00:51:52,766 --> 00:51:54,366
BUT BECAUSE YOU CAN HAVE--

1181
00:51:54,366 --> 00:51:56,200
YOU HAVE THE STORAGE
ASSOCIATED WITH IT,

1182
00:51:56,200 --> 00:51:58,300
THEN IT MAKES IT
EXTREMELY VALUABLE.

1183
00:51:58,300 --> 00:52:00,166
YOU CAN REALLY PRODUCE
ANY PROFILE YOU WANT

1184
00:52:00,166 --> 00:52:02,233
OF ELECTRICITY PRODUCTION.

1185
00:52:02,233 --> 00:52:03,933
SO IT'S DEFINITELY
WORTH USING.

1186
00:52:03,933 --> 00:52:06,366
SO THAT'S WHY WE TRY TO PUT IT
AS MANY PLACES AS POSSIBLE.

1187
00:52:06,366 --> 00:52:08,333
BUT YOU NEED DIRECT
SOLAR RADIATION.

1188
00:52:08,333 --> 00:52:11,066
YOU CAN'T USE DIFFUSE RADIATION
TOO MUCH.

1189
00:52:11,066 --> 00:52:13,733
- WELL, THANK YOU SO MUCH
FOR COMING.

1190
00:52:13,733 --> 00:52:15,466
I HAD A COUPLE OF QUESTIONS.

1191
00:52:15,466 --> 00:52:18,933
YOU TALKED ABOUT THE AREA OF,
LIKE, WIND TURBINES AND THINGS.

1192
00:52:18,933 --> 00:52:20,833
BUT WHAT ABOUT THE MATERIAL
THAT'S NEEDED

1193
00:52:20,833 --> 00:52:23,100
TO ACTUALLY MAKE THESE
AND MANUFACTURE THEM?

1194
00:52:23,100 --> 00:52:24,600
SO MANUFACTURING PLANTS,
THE COST--

1195
00:52:24,600 --> 00:52:26,133
OR, YOU TALKED ABOUT THE COST,

1196
00:52:26,133 --> 00:52:28,266
BUT MORE OF LIKE THE ENERGY
REQUIRED TO MAKE THESE.

1197
00:52:28,266 --> 00:52:31,633
AND THEN ALSO YOU TALKED ABOUT
HOW WIND TURBINES OFF THE COAST

1198
00:52:31,633 --> 00:52:35,533

CAN REDUCE WINDS
FROM HURRICANES,

1199
00:52:35,533 --> 00:52:38,000
BUT HOW CAN THAT BE NEGATIVELY
SEEN AS WELL?

1200
00:52:38,000 --> 00:52:39,700
SO WE MIGHT
BE CHANGING THE CLIMATE

1201
00:52:39,700 --> 00:52:42,000
WHEN WE PUT THESE
WIND TURBINES UP.

1202
00:52:42,000 --> 00:52:43,766
DO YOU--HAVE YOU SEEN
RESEARCH DONE,

1203
00:52:43,766 --> 00:52:45,366
OR DO YOU HAVE KNOWLEDGE

1204
00:52:45,366 --> 00:52:48,100
OF HOW IT MIGHT ACTUALLY BE
REFLECTED IN A NEGATIVE WAY,

1205
00:52:48,100 --> 00:52:51,366
OR IN A DIFFERENT TYPE
OF CLIMATE STRUCTURE.

1206
00:52:51,366 --> 00:52:53,566
- YEAH. LET ME ANSWER
THE FIRST QUESTION.

1207
00:52:53,566 --> 00:52:57,066
THE ENERGY EMBODIED IN PRODUCING
A WIND TURBINE

1208
00:52:57,066 --> 00:53:01,466
IS ABOUT THREE TO SIX MONTHS

OF RUNNING THE TURBINE.

1209
00:53:01,466 --> 00:53:04,900
SO THE TURBINE LIFETIME'S
ABOUT 30 YEARS.

1210
00:53:04,900 --> 00:53:06,900
AND SO FOR THE FIRST
THREE TO SIX MONTHS,

1211
00:53:06,900 --> 00:53:09,366
YOU'RE BASICALLY GENERATING
THE ELECTRICITY YOU NEED

1212
00:53:09,366 --> 00:53:12,233
TO PRODUCE THE--WHICH MIGHT HAVE
BEEN FROM FOSSIL FUEL.

1213
00:53:12,233 --> 00:53:14,933
SO IT'S ABOUT 98% CARBON-FREE

1214
00:53:14,933 --> 00:53:17,600
IF YOU USE TODAY'S ENERGY
INFRASTRUCTURE.

1215
00:53:17,600 --> 00:53:19,833
BUT EVENTUALLY, IF WE HAVE
100% RENEWABLE ENERGY,

1216
00:53:19,833 --> 00:53:21,866
THEN THERE'D BE 100%
CARBON-FREE.

1217
00:53:21,866 --> 00:53:25,900
IN TERMS OF METALS,
LIKE, YOU NEED STEEL AND CEMENT.

1218
00:53:25,900 --> 00:53:28,300
BUT YOU ALSO NEED
SOME RARE EARTH ELEMENTS.

1219
00:53:28,300 --> 00:53:31,633
BUT WE'VE LOOKED AT THE RARE
EARTH, LIKE NEODYMIUM.

1220
00:53:31,633 --> 00:53:35,833
THERE'S ABOUT SEVEN TIMES MORE
NEODYMIUM AVAILABLE RESOURCES

1221
00:53:35,833 --> 00:53:38,133
THAN YOU NEED TO PROVIDE
ALL THE WIND TURBINES YOU NEED

1222
00:53:38,133 --> 00:53:39,566
TO POWER THE WORLD.

1223
00:53:39,566 --> 00:53:42,900
IN TERMS OF THE WIND TURBINE
IT IMPACTS, WE DID TWO STUDIES.

1224
00:53:42,900 --> 00:53:46,066
ONE LOOKING AT--COVERING THE
ENTIRE WORLD WITH WIND TURBINES.

1225
00:53:46,066 --> 00:53:48,066
COVERING ALL LAND
WITH WIND TURBINES,

1226
00:53:48,066 --> 00:53:49,500
AND THEN PUTTING FOUR MILLION
WIND TURBINES,

1227
00:53:49,500 --> 00:53:51,833
WHICH WOULD BE ENOUGH
TO POWER 50% OF THE WORLD.

1228
00:53:51,833 --> 00:53:55,600
AND IN THE FOUR MILLION CASE,
WHICH IS THE PRACTICAL CASE,

1229
00:53:55,600 --> 00:53:57,566
THERE'S VIRTUALLY NO
LARGE-SCALE IMPACT.

1230
00:53:57,566 --> 00:53:59,200
YOU GOT LOCAL IMPACTS
DOWNWIND.

1231
00:53:59,200 --> 00:54:01,333
YOU'LL REDUCE WIND SPEEDS
LOCALLY.

1232
00:54:01,333 --> 00:54:04,033
BUT IF YOU COVER THE U.S.
OR THE WORLD,

1233
00:54:04,033 --> 00:54:05,800
WHAT YOU'LL FIND IS ACTUALLY
THEY COOL THE CLIMATE.

1234
00:54:05,800 --> 00:54:08,000
IN FACT, WIND TURBINES
WILL COOL THE CLIMATE.

1235
00:54:08,000 --> 00:54:11,066
THEY WARM THE LAND LOCALLY,
RIGHT DOWNWIND OF THE TURBINES,

1236
00:54:11,066 --> 00:54:13,166
BECAUSE THEY REDUCE
EVAPORATION,

1237
00:54:13,166 --> 00:54:14,733
AND EVAPORATION
IS A COOLING PROCESS.

1238
00:54:14,733 --> 00:54:18,000
SO IF YOU HAVE LESS EVAPORATION
YOU WARM THE--WARM THE LAND.

1239
00:54:18,000 --> 00:54:19,533
BUT BECAUSE YOU HAVE
LESS WATER IN THE AIR,

1240
00:54:19,533 --> 00:54:21,466
YOU GOT LESS CONDENSATION
IN THE AIR.

1241
00:54:21,466 --> 00:54:23,466
AND CONDENSATION'S
A WARMING PROCESS.

1242
00:54:23,466 --> 00:54:25,933
SO IF YOU HAVE LESS
CONDENSATION, YOU COOL THE AIR.

1243
00:54:25,933 --> 00:54:27,500
SO THOSE TWO THINGS
OFFSET EACH OTHER

1244
00:54:27,500 --> 00:54:28,800
IN TERMS OF TEMPERATURE.

1245
00:54:28,800 --> 00:54:30,833
BUT BECAUSE YOU NOW HAVE
LESS WATER VAPOR IN THE AIR,

1246
00:54:30,833 --> 00:54:33,433
WHICH IS A GREENHOUSE GAS,
YOU CAUSE LESS GLOBAL WARMING.

1247
00:54:33,433 --> 00:54:35,933
IT'S THE MOST ABUNDANT
NATURAL GREENHOUSE GAS.

1248
00:54:35,933 --> 00:54:38,666
SO WE FOUND THAT THERE'S
A NET COOLING OF CLIMATE

1249

00:54:38,666 --> 00:54:41,166
DUE TO PUTTING ALL THESE WIND
TURBINES UP.

1250
00:54:41,166 --> 00:54:42,866
BUT AT THE NUMBERS
WE'RE TALKING ABOUT:

1251
00:54:42,866 --> 00:54:46,000
FOUR MILLION WIND TURBINES
FOR HALF THE WORLD'S ENERGY,

1252
00:54:46,000 --> 00:54:49,766
IT'S REALLY A TRIVIAL IMPACT
ON THE WATER BUDGET OVERALL.

1253
00:54:49,766 --> 00:54:52,000
YOU'LL GET LOCAL IMPACTS,
REDUCING WIND SPEEDS,

1254
00:54:52,000 --> 00:54:54,433
MAYBE CHANGING THE PRECIPITATION
LOCALLY.

1255
00:54:54,433 --> 00:54:57,433
BUT YOU'RE NOT GOING TO HAVE
LARGE-SCALE CLIMATE IMPACTS

1256
00:54:57,433 --> 00:54:59,466
FROM THOSE TURBINES.

1257
00:55:01,200 --> 00:55:02,666
- HI. THAT WAS A GREAT TALK.

1258
00:55:02,666 --> 00:55:05,633
I WAS JUST WONDERING
IF THE PLANS

1259
00:55:05,633 --> 00:55:09,566
LOOKED INTO DISTRIBUTION

LOGISTICS.

1260
00:55:09,566 --> 00:55:13,633
SO DISTRIBUTING PLACES
THAT HAVE HIGH SOLAR ENERGY

1261
00:55:13,633 --> 00:55:18,633
AND HIGH WIND SPEEDS TO AREAS
THAT NEED THE ENERGY TO USE.

1262
00:55:18,633 --> 00:55:20,600
- WELL, SO THE TRANSMISSION
SYSTEM.

1263
00:55:20,600 --> 00:55:23,733
THAT'S KIND OF WHERE
ONE OF THE BARRIERS IS.

1264
00:55:23,733 --> 00:55:25,500
NOT SO MUCH TECHNICAL
OR ECONOMIC.

1265
00:55:25,500 --> 00:55:28,100
YOU WOULD--WELL, IN THE U.S.
YOU HAVE A LOT OF WIND

1266
00:55:28,100 --> 00:55:29,433
IN THE GREAT PLAINS,
FOR EXAMPLE.

1267
00:55:29,433 --> 00:55:32,133
YOU ALSO HAVE A LOT OF WINDS
OFFSHORE THE EAST COAST.

1268
00:55:32,133 --> 00:55:34,666
AND--BUT EVERY STATE
HAS SOME WIND,

1269
00:55:34,666 --> 00:55:36,600
EXCEPT IN THE SOUTH,

IT'S NOT THAT GREAT.

1270
00:55:36,600 --> 00:55:38,366
BUT THERE ARE STILL PLACES
IN THE SOUTH.

1271
00:55:38,366 --> 00:55:41,666
SO YOU WOULD--AND THE SAME THING
WITH SOLAR.

1272
00:55:41,666 --> 00:55:43,100
YOU HAVE A LOT OF SOLAR
IN THE SOUTHWEST,

1273
00:55:43,100 --> 00:55:45,300
BUT EVERY STATE HAS SOME
AMOUNT OF SOLAR.

1274
00:55:45,300 --> 00:55:46,633
BUT IN PARTICULAR FOR WIND,

1275
00:55:46,633 --> 00:55:48,500
YOU MIGHT NEED LONG-DISTANCE
TRANSMISSION.

1276
00:55:48,500 --> 00:55:50,366
SO THERE'S JUST GOING
TO BE A BALANCE.

1277
00:55:50,366 --> 00:55:52,033
TAKE, FOR EXAMPLE,
IN THE EAST COAST.

1278
00:55:52,033 --> 00:55:55,400
IS IT LESS EXPENSIVE
TO BUILD OFFSHORE WIND,

1279
00:55:55,400 --> 00:55:58,100
WHICH YOU HAVE VERY LITTLE
TRANSMISSION

1280
00:55:58,100 --> 00:56:01,133
AND IT'S RIGHT NEXT
TO WHERE PEOPLE LIVE,

1281
00:56:01,133 --> 00:56:04,333
OR HAVE WIND THAT'S 2 CENTS
A KILOWATT HOUR

1282
00:56:04,333 --> 00:56:05,600
IN THE GREAT PLAINS,

1283
00:56:05,600 --> 00:56:07,233
AND THEN BUILD TRANSMISSION
TO THE EAST COAST?

1284
00:56:07,233 --> 00:56:08,966
I MEAN, THAT'S THE QUESTION
THAT ARISES.

1285
00:56:08,966 --> 00:56:10,433
I MEAN, THERE'S ALREADY
A TRANSMISSION GRID

1286
00:56:10,433 --> 00:56:12,300
ACROSS THE WHOLE U.S.

1287
00:56:12,300 --> 00:56:15,733
THE QUESTION--YOU'LL PROBABLY
NEED TO ENHANCE IT.

1288
00:56:15,733 --> 00:56:17,533
AND THAT'S MORE
OF A ZONING ISSUE.

1289
00:56:17,533 --> 00:56:19,500
A LOT OF PEOPLE JUST DON'T WANT
TO ADD TRANSMISSION.

1290

00:56:19,500 --> 00:56:21,733
AND SO IT'S NOT A TECHNICAL
OR ECONOMIC ISSUE,

1291
00:56:21,733 --> 00:56:23,700
BUT IT IS A POLITICAL ISSUE.

1292
00:56:23,700 --> 00:56:25,233
AND THAT'S ONE OF THE POSSIBLE
BARRIERS

1293
00:56:25,233 --> 00:56:27,566
TO DOING THIS
ON A LARGE SCALE.

1294
00:56:29,133 --> 00:56:32,633
- SO PLEASE JOIN ME IN THANKING
DR. MARK JACOBSON

1295
00:56:32,633 --> 00:56:34,333
FOR AN EXCELLENT PRESENTATION.

1296
00:56:34,333 --> 00:56:35,966
THANK YOU VERY MUCH.

1297
00:56:35,966 --> 00:56:39,433
[applause]