WEBVTT

1 00:00:00.360 --> 00:00:04.410 <v Host>Welcome to the first seminar of our seminar series</v>

2 00:00:04.410 --> 00:00:06.480 in Climate, Air, and Health.

3 00:00:06.480 --> 00:00:09.013 We have some online audiences joining us today,

4 00:00:09.013 --> 00:00:12.310 and before we get started, just wanted to let you know that

5 00:00:12.310 --> 00:00:15.393 this seminar is recorded, and later on,

6 00:00:15.393 --> 00:00:19.470 the recording will be posted on our center's website.

7 00:00:19.470 --> 00:00:20.490 On the monitor today,

8 00:00:20.490 --> 00:00:22.050 I have chosen assistant professor

9 00:00:22.050 --> 00:00:24.085 at Yale School of Public Health,

10 00:00:24.085 --> 00:00:25.177 and also the director of research

11 00:00:25.177 --> 00:00:27.060 at Yale School of Public Health.

12 00:00:27.060 --> 00:00:29.550 So, it's my great pleasure today

13 00:00:29.550 --> 00:00:34.143 to introduce our very first speaker, Dr. Drew Gentner.

14 00:00:35.100 --> 00:00:39.480 Dr. Gentner is the associate professor in the department

15 00:00:39.480 --> 00:00:41.670 of chemical and environmental engineering.

16 00:00:41.670 --> 00:00:44.427 Also, the department of the School of the Environment.

17 00:00:44.427 --> 00:00:48.442 He got his master and the PhD from UC Berkeley,

18 00:00:48.442 --> 00:00:52.110 and also he has been at the Department of Chemical

19 00:00:52.110 --> 00:00:56.100 and Environmental Engineering since 2014,

20 00:00:56.100 --> 00:00:58.050 where his research group focuses on

21 00:00:58.050 --> 00:01:02.910 air quality, pollution, emissions, and chemistry.

22 00:01:02.910 --> 00:01:05.740 His application in books and [Indistinct].

23 00:01:06.848 --> 00:01:10.300 And today we are very fortunate to have both Dr Gentner,

24 00:01:11.511 --> 00:01:15.150 and also Professor Gillingham joining us online.

25 00:01:15.150 --> 00:01:20.150 Today the main topic will be focusing on their recent paper,

26 00:01:21.150 --> 00:01:23.128 the Climate and Health Benefits

27 00:01:23.128 --> 00:01:26.013 from Intensive Building Energy Efficiency.

28 00:01:26.970 --> 00:01:29.280 So without further ado, please.

29 00:01:29.280 --> 00:01:31.110 <v Dr. Gentner>Thank you so much.</v>

30 00:01:31.110 --> 00:01:34.260 And my one request of the virtual audience

31 00:01:34.260 --> 00:01:37.050 is let me know if you can't hear me clearly.

32 00:01:37.050 --> 00:01:40.320 I will try to speak loudly and through a mask,

33 00:01:40.320 --> 00:01:43.230 but just chime in if you're having trouble

34 00:01:43.230 --> 00:01:45.733 and I'll stay closer to my computer.

35 00:01:45.733 --> 00:01:50.733 Alright so, you have both and Ken and I here today,

36 00:01:51.720 --> 00:01:54.270 and I wish he could have been here in person,

37 00:01:54.270 --> 00:01:57.820 but I get to present this paper that we worked on along with

38 00:01:58.950 --> 00:02:02.340 Professor Jordan Peccia in Environmental Engineering,

39 00:02:02.340 --> 00:02:04.380 a PhD student of mine, Colby Buehler,

40 00:02:04.380 --> 00:02:06.720 and former postdoc of Ken's

41 00:02:06.720 --> 00:02:08.460 from the School of the Environment.

42 00:02:08.460 --> 00:02:10.560 So, this was a cool project

43 00:02:10.560 --> 00:02:12.240 that we were really excited about because

44 00:02:12.240 --> 00:02:14.970 it was a true interdisciplinary science

45 00:02:14.970 --> 00:02:18.090 where I was excited to work with Ken

46 00:02:18.090 --> 00:02:20.340 to do some energy modeling, and then bring that

47 00:02:20.340 --> 00:02:23.820 into looking at outdoor and indoor air quality

48 00:02:23.820 --> 00:02:25.830 across the building envelope.

49 00:02:25.830 --> 00:02:27.662 And so, this brought in some expertise

50 00:02:27.662 --> 00:02:31.890 from Professor Peccia and I to look at air pollution,

51 00:02:31.890 --> 00:02:34.290 and then extend it to the health effects.

52 00:02:34.290 --> 00:02:38.193 This fell under the purview of, our,

53 00:02:39.510 --> 00:02:41.730 hopefully I can click here.

54 00:02:41.730 --> 00:02:45.450 Alright, of our search center,

55 00:02:45.450 --> 00:02:48.570 which I, Michelle Bell has been the director

56 00:02:48.570 --> 00:02:51.240 of up at the School of the Environment,

57 00:02:51.240 --> 00:02:54.687 and we're in our last year at the center now.

58 00:02:54.687 --> 00:02:57.090 But the overall objectives of this were to look at energy

59 00:02:57.090 --> 00:02:59.460 transitions and look at the the wide range

60 00:02:59.460 --> 00:03:02.520 of sources related to energy production use,

61 00:03:02.520 --> 00:03:04.170 in the context of other sources

62 00:03:04.170 --> 00:03:07.530 that attract urban air quality and health.

63 00:03:07.530 --> 00:03:09.570 And then, we paid key attention to both

64 00:03:09.570 --> 00:03:11.730 transitions and key modifiable factors.

65 00:03:11.730 --> 00:03:13.110 So which things can we change,

66 00:03:13.110 --> 00:03:15.152 either through policy or personal choices,

67 00:03:15.152 --> 00:03:17.130 so that we can make smarter decisions

68 00:03:17.130 --> 00:03:19.500 related to transportation, land use,

69 00:03:19.500 --> 00:03:23.040 our power generation, and distribution networks.

70 00:03:23.040 --> 00:03:24.510 So, this had a number of different

71 00:03:24.510 --> 00:03:27.690 projects involved with it.

72 00:03:27.690 --> 00:03:31.860 Ken's project was number one and mine was number two.

73 00:03:31.860 --> 00:03:34.950 We were doing this in collaboration with Johns Hopkins,

74 00:03:34.950 --> 00:03:36.660 and we had a couple other projects.

75 00:03:36.660 --> 00:03:38.280 And so these things,

76 00:03:38.280 --> 00:03:43.280 we're focused on distinctly different areas of air quality

77 00:03:44.520 --> 00:03:47.520 where I was focused more on source characterization

78 00:03:47.520 --> 00:03:50.250 and measurements in project two and Ken was doing

79 00:03:50.250 --> 00:03:52.440 a lot of modeling on energy and emissions.

80 00:03:52.440 --> 00:03:55.620 So this project represented, and this paper,

81 00:03:55.620 --> 00:03:59.130 one of a couple things that we were doing has inter-center

82 00:03:59.130 --> 00:04:03.630 collaboration within a much larger center structure.

83 00:04:03.630 --> 00:04:05.100 <v ->And you can check it out online</v>

84 00:04:05.100 --> 00:04:07.170 and see a lot of the other great work

85 00:04:07.170 --> 00:04:08.880 coming out of Michelle Bell's group

86 00:04:08.880 --> 00:04:11.250 and others at Yale, Johns Hopkins,

87 00:04:11.250 --> 00:04:13.353 and our partner institutions.

88 00:04:14.460 --> 00:04:19.127 Which span some co-PIs at Johns Hopkins, and other PI's,

89 00:04:20.268 --> 00:04:24.813 and Dan Esty, at the School of the Environment.

90 00:04:25.920 --> 00:04:30.150 So, onto this paper. So, now it's like dive in and focus.

91 00:04:30.150 --> 00:04:33.180 This started, I can actually remember the workshop

92 00:04:33.180 --> 00:04:35.760 that Ken and I were at when we were talking

93 00:04:35.760 --> 00:04:38.220 about this research question.

94 00:04:38.220 --> 00:04:40.930 Thinking about how the climate and health

95 00:04:40.930 --> 00:04:44.040 benefits intersect when we look at

96 00:04:44.040 --> 00:04:46.320 building energy efficiency measures.

97 00:04:46.320 --> 00:04:48.900 'Cause Ken's group was thinking about

98 00:04:48.900 --> 00:04:51.270 building energy efficiency scenarios,

99 00:04:51.270 --> 00:04:55.590 how we reduce energy use in the building sector to reduce

100 00:04:55.590 --> 00:05:00.590 C02 emissions and affect change for climate mitigation.

101 00:05:01.260 --> 00:05:03.570 And I started asking, well Ken,

102 00:05:03.570 --> 00:05:06.090 what about the indoor air quality on that?

103 00:05:06.090 --> 00:05:08.520 You know, we're gonna drop emissions of pollution

104 00:05:08.520 --> 00:05:10.890 outdoors from reduced energy production,

105 00:05:10.890 --> 00:05:12.630 but what happens with the

106 00:05:12.630 --> 00:05:14.037 building energy efficiency measures?

107 00:05:14.037 --> 00:05:18.933 And so, thus this project and this paper was born.

108 00:05:20.970 --> 00:05:24.030 As a brief overview of where we're going with this today,

109 00:05:24.030 --> 00:05:25.920 we start with the fact that buildings

110 00:05:25.920 --> 00:05:28.023 account for 40% of energy usage,

111 00:05:29.130 --> 00:05:32.910 a lot of our energy command nationally.

112 00:05:32.910 --> 00:05:36.450 So, it makes it a really prime target for

113 00:05:36.450 --> 00:05:39.754 climate change mitigation and producing

114 00:05:39.754 --> 00:05:43.650 both energy use and associated emissions.

115 00:05:43.650 --> 00:05:46.380 These are emissions of not only climate pollutants,

116 00:05:46.380 --> 00:05:49.136 but also air pollutants, slight particulate

117 00:05:49.136 --> 00:05:53.640 matter sulfur dioxide, carbon dioxide, nitrogen oxide.

118 00:05:53.640 --> 00:05:58.080 So, with these scenarios that I'll show you in a moment,

119 00:05:58.080 --> 00:06:00.930 we looked at reductions in energy related emissions

120 00:06:00.930 --> 00:06:03.723 that would be occurring outdoors from power generation,

121 00:06:04.590 --> 00:06:07.110 and then translated that to its

122 00:06:07.110 --> 00:06:08.790 effects on indoor air quality.

123 00:06:08.790 --> 00:06:12.393 And, I'll talk about that feedback loop in a moment.

124 00:06:13.320 --> 00:06:18.320 But, the approach here is to use the Yale-NEMS model,

125 00:06:19.260 --> 00:06:23.040 which Ken runs up at school of the environment,

126 00:06:23.040 --> 00:06:25.050 to look at energy efficiency scenarios

127 00:06:25.050 --> 00:06:27.060 across the entire US housing stock.

128 00:06:27.060 --> 00:06:29.550 So we're not just studying one building,

129 00:06:29.550 --> 00:06:32.511 we model all the homes of the US and their changes

130 00:06:32.511 --> 00:06:36.207 over time with a lot of simulations

131 00:06:36.207 --> 00:06:39.873 and a couple models that were interconnected.

132 00:06:39.873 --> 00:06:41.400 Then we evaluated the outdoor

133 00:06:41.400 --> 00:06:42.930 indoor air quality implications.

134 00:06:42.930 --> 00:06:46.080 So how do the changes in emissions

135 00:06:46.080 --> 00:06:50.160 affect exposure and human health,

136 00:06:50.160 --> 00:06:52.320 both for outdoor and indoor exposure pathways,

137 00:06:52.320 --> 00:06:53.370 and look at the bad effects

138 00:06:53.370 --> 00:06:56.013 on human health, all of these together.

139 00:06:57.000 --> 00:07:00.930 So, I'll walk through this in a bit more detail,

140 00:07:00.930 --> 00:07:02.880 but we start from something where

141 00:07:02.880 --> 00:07:05.610 we take a reference scenario,

142 00:07:05.610 --> 00:07:07.230 an intermediate energy efficiency

143 00:07:07.230 --> 00:07:08.940 scenario just for buildings.

144 00:07:08.940 --> 00:07:12.151 An optimistic energy efficiency scenario for buildings

145 00:07:12.151 --> 00:07:15.480 and look at the changes in energy consumption

146 00:07:15.480 --> 00:07:17.910 and then test the carbon pricing scenario

147 00:07:17.910 --> 00:07:21.060 for those to see how that affects it.

148 00:07:21.060 --> 00:07:22.890 And we'll walk through this before,

149 00:07:22.890 --> 00:07:24.450 but if you fast forward all the way,

150 00:07:24.450 --> 00:07:26.670 you can see how we will then be able

151 00:07:26.670 --> 00:07:29.610 to look at projections in particular manner,

152 00:07:29.610 --> 00:07:33.213 emissions from that reduced energy use.

153 00:07:34.380 --> 00:07:38.700 So, the scenarios, without going into them in great detail,

154 00:07:38.700 --> 00:07:40.710 although there's a lot of information in the paper

155 00:07:40.710 --> 00:07:43.500 and tech would be happy to answer questions,

156 00:07:43.500 --> 00:07:46.440 looks at changes in both appliances and equipment

157 00:07:46.440 --> 00:07:48.030 and in the building shell.

158 00:07:48.030 --> 00:07:50.250 So we have all of this stuff indoors

159 00:07:50.250 --> 00:07:53.460 for heating, cooling, cooking, lighting,

160 00:07:53.460 --> 00:07:57.660 and other things like refrigeration

161 00:07:57.660 --> 00:07:59.550 and those have a certain amount of energy use with them,

162 00:07:59.550 --> 00:08:00.750 and that's been a target of a lot

163 00:08:00.750 --> 00:08:03.120 of governmental programs through efficiency.

164 00:08:03.120 --> 00:08:05.820 You know, you can go and buy energy star things,

165 00:08:05.820 --> 00:08:08.550 you see them when you go to the store,

166 00:08:08.550 --> 00:08:12.090 and so, there are targets related to the energy efficiency.

167 00:08:12.090 --> 00:08:15.750 And then in the building shell is where we start to look

168 00:08:15.750 --> 00:08:19.110 at the interconnections at indoor air quality.

169 00:08:19.110 --> 00:08:21.570 'Cause the indoor environment is really complex.

170 00:08:21.570 --> 00:08:23.070 The air that gets to us here,

171 00:08:23.070 --> 00:08:26.580 or the air in your home navigates a lot of places.

172 00:08:26.580 --> 00:08:29.520 Either through a forced air system or just naturally,

173 00:08:29.520 --> 00:08:33.270 you have some penetration coming through the walls,

174 00:08:33.270 --> 00:08:34.763 and some infiltration of air,

175 00:08:34.763 --> 00:08:36.540 and the pollutants coming in,

176 00:08:36.540 --> 00:08:38.400 and some ventilation of the air going out.

177 00:08:38.400 --> 00:08:42.150 You may do that on purpose, opening you know, a door,

178 00:08:42.150 --> 00:08:46.260 turning on a fan, or that might just be happening naturally,

179 00:08:46.260 --> 00:08:48.000 and depending on the age of your home

180 00:08:48.000 --> 00:08:49.320 and how well it's sealed,

181 00:08:49.320 --> 00:08:51.930 that could be happening at quite a high rate.

182 00:08:51.930 --> 00:08:55.740 So, we look at the changes in the building shell

183 00:08:55.740 --> 00:08:57.210 across a range of environments,

184 00:08:57.210 --> 00:08:59.610 and we're gonna talk more about residences today,

185 00:08:59.610 --> 00:09:02.070 'cause that's where we do spend most

186 00:09:02.070 --> 00:09:04.657 of our time and a lot of our time,

187 00:09:04.657 --> 00:09:09.210 a lot of our PM2.5 emissions indoors

188 00:09:09.210 --> 00:09:10.680 occur in our residences.

189 00:09:10.680 --> 00:09:12.660 So we'll look at that, and we'll look these scenarios

190 00:09:12.660 --> 00:09:15.390 where we have existing homes and we look at changes

191 00:09:15.390 --> 00:09:18.450 in efficiency that happen at slower incremental rates.

192 00:09:18.450 --> 00:09:20.580 And then new homes that are built

193 00:09:20.580 --> 00:09:25.080 to the newest specifications which follow these

194 00:09:25.080 --> 00:09:28.383 ambitious but demonstrated improvements.

195 00:09:29.490 --> 00:09:34.320 So Ken's model, which is the national energy modeling

196 00:09:34.320 --> 00:09:38.367 system model that is the scale installation of this,

197 00:09:38.367 --> 00:09:42.093 and the launch model developed by the US EIA,

198 00:09:44.070 --> 00:09:46.260 covers a whole lot of things in the supply side,

199 00:09:46.260 --> 00:09:47.850 convergence side, and demand side,

200 00:09:47.850 --> 00:09:50.160 electricity, and integrates it together.

201 00:09:50.160 --> 00:09:53.640 So, where we're gonna focus on today for this paper

202 00:09:53.640 --> 00:09:55.710 is looking at the changes in the residential demand

203 00:09:55.710 --> 00:09:58.560 and commercial demand that are derived

204 00:09:58.560 --> 00:10:01.203 from these changes in energy efficiency.

205 00:10:02.220 --> 00:10:04.410 So if we change the design of a building,

206 00:10:04.410 --> 00:10:07.290 we are changing the energy in the air there,

207 00:10:07.290 --> 00:10:10.830 and that has feedbacks to reduce demand,

208 00:10:10.830 --> 00:10:13.473 to increase production and thus we have changes.

209 00:10:15.120 --> 00:10:18.480 So, there are a lot of things that are in this model,

210 00:10:18.480 --> 00:10:20.610 and if you are a big fan of supplemental

211 00:10:20.610 --> 00:10:22.740 information sections and papers,

212 00:10:22.740 --> 00:10:26.130 I encourage you to check out the,

213 00:10:26.130 --> 00:10:29.890 somewhere around 55 pages that exist in the paper

214 00:10:31.050 --> 00:10:34.180 with hopefully, every question that you might have

215 00:10:35.880 --> 00:10:39.090 about the energy modeling system and then hence,

216 00:10:39.090 --> 00:10:40.833 other work using this model.

217 00:10:41.700 --> 00:10:44.490 And so, if we look at the scenarios,

218 00:10:44.490 --> 00:10:48.840 you have the reference case at the top here in red

219 00:10:48.840 --> 00:10:53.840 that we play around the carbon pricing initiative on there.

220 00:10:53.970 --> 00:10:56.220 Now we look at the intermediate energy efficiency,

221 00:10:56.220 --> 00:10:58.422 just for buildings here and see that that drops

222 00:10:58.422 --> 00:11:01.365 consumption down somewhat than a more optimistic

223 00:11:01.365 --> 00:11:04.290 one with without carbon pricing.

224 00:11:04.290 --> 00:11:07.020 The direct effects on carbon dioxide emissions are shown

225 00:11:07.020 --> 00:11:10.530 over here where you can actually see a pretty sizable effect

226 00:11:10.530 --> 00:11:12.690 on overall carbon dioxide emissions

227 00:11:12.690 --> 00:11:15.900 just from building energy efficiency improvements.

228 00:11:15.900 --> 00:11:19.110 So, this really points back to that fact that

229 00:11:19.110 --> 00:11:24.110 40% of our energy use occurs in maintaining

230 00:11:24.990 --> 00:11:26.460 our buildings and in our buildings.

231 00:11:26.460 --> 00:11:29.253 So, any change that we make here,

232 00:11:30.270 --> 00:11:33.210 a policy level has a pretty sizable effect

233 00:11:33.210 --> 00:11:37.203 on energy demand and related climate pollute emissions.

234 00:11:39.210 --> 00:11:44.210 This also has a sizable effect on air pollutant emissions

235 00:11:44.250 --> 00:11:48.400 like criteria pollutants for particular matter, NOx.

236 00:11:48.400 --> 00:11:53.400 SO2, VOCs, a sub effect on ammonia and carbon dioxide,

237 00:11:54.257 --> 00:11:56.725 excuse me, carbon monoxide,

238 00:11:56.725 --> 00:12:01.375 though today we're gonna focus mostly on PM2.5,

239 00:12:01.375 --> 00:12:06.375 since that is driving factor of premature mortality,

240 00:12:06.390 --> 00:12:11.390 and what's the key pollutant of interest for this paper.

241 00:12:11.700 --> 00:12:14.760 So here we've defined what the changes are

242 00:12:14.760 --> 00:12:18.570 for each of these scenarios over this time rise

243 00:12:18.570 --> 00:12:22.530 and extending to 2050 for the energy related

244 00:12:22.530 --> 00:12:24.210 emissions that are occurring outdoors.

245 00:12:24.210 --> 00:12:25.980 So if you wanna visualize it,

246 00:12:25.980 --> 00:12:30.980 what's coming out of the smokestack for PM2.5 emissions.

247 00:12:31.680 --> 00:12:33.930 So that's gonna vary a little bit across the country

248 00:12:33.930 --> 00:12:36.150 where we generate that power, how we generate it.

249 00:12:36.150 --> 00:12:39.060 And so we'll talk about that at the end

250 00:12:39.060 --> 00:12:41.163 of the presentation today.

251 00:12:43.290 --> 00:12:48.290 So, we spend close to 90% of our time indoors, so,

252 00:12:50.670 --> 00:12:53.520 so we're thinking about exposure to pollutants.

253 00:12:53.520 --> 00:12:55.050 We really need to be considering that

254 00:12:55.050 --> 00:12:58.590 indoor environment and how it modulates our exposure

255 00:12:58.590 --> 00:13:02.010 to pollution coming in from outdoors,

256 00:13:02.010 --> 00:13:05.607 but also how it affects,

257 00:13:05.607 --> 00:13:06.996 how the design of that indoor environment

258 00:13:06.996 --> 00:13:10.953 affects our exposure to pollutants that are generated.

259 00:13:12.630 --> 00:13:15.270 Now, I wish I had Jordan Peccia here with me today,

260 00:13:15.270 --> 00:13:18.930 so he could answer all of your COVID-related questions,

261 00:13:18.930 --> 00:13:21.660 relating to ventilation and filtration,

262 00:13:21.660 --> 00:13:23.910 because that is not my area of expertise.

263 00:13:23.910 --> 00:13:27.810 But you can take this admissions term here,

264 00:13:27.810 --> 00:13:32.160 and think really about whatever pollutant or microbe

265 00:13:32.160 --> 00:13:35.880 or anything that you want, for your own work,

266 00:13:35.880 --> 00:13:38.820 and think about how that's affected by the design

267 00:13:38.820 --> 00:13:42.783 of your home or the space that you're currently in.

268 00:13:44.190 --> 00:13:45.510 This is a box model.

269 00:13:45.510 --> 00:13:48.870 It is actually simplified considerably,

270 00:13:48.870 --> 00:13:53.040 to just a singular box representing a space indoors.

271 00:13:53.040 --> 00:13:57.390 But yes, there's still one equation. For that, I apologize.

272 00:13:57.390 --> 00:13:58.950 You can ignore the equation if you like,

273 00:13:58.950 --> 00:14:01.030 I can try to cover it up and we can

274 00:14:01.030 --> 00:14:04.470 focus on the terms that are used here.

275 00:14:04.470 --> 00:14:05.720 So, I'm going to point out a few things

276 00:14:05.720 --> 00:14:07.380 on how the model connects,

277 00:14:07.380 --> 00:14:10.470 just to try to show how this all comes together.

278 00:14:10.470 --> 00:14:15.470 So first thing, we have recirculation with a filter.

279 00:14:15.660 --> 00:14:18.780 Now you're predominantly talking about HVAC system.

280 00:14:18.780 --> 00:14:22.110 So, forced mechanical air filtration system

281 00:14:22.110 --> 00:14:23.970 that you would have in an indoor building.

282 00:14:23.970 --> 00:14:26.460 You have them here, your apartment,

283 00:14:26.460 --> 00:14:28.320 perhaps up the east rock,

284 00:14:28.320 --> 00:14:33.240 that was built 80, 90 years ago may not have that,

285 00:14:33.240 --> 00:14:37.950 or some newer builds don't have of course, HVAC system,

286 00:14:37.950 --> 00:14:39.750 but that is where you would have some

287 00:14:39.750 --> 00:14:42.213 active particle filtration that's occurring.

288 00:14:43.200 --> 00:14:47.410 Now in the the era of thinking about filtering for

289 00:14:48.930 --> 00:14:51.990 you know, viruses and other microbes doors,

290 00:14:51.990 --> 00:14:53.940 whether it be COVID or otherwise.

291 00:14:53.940 --> 00:14:56.370 We've started to put in some affordable air filters,

292 00:14:56.370 --> 00:14:57.900 so you could also think about that,

293 00:14:57.900 --> 00:14:59.550 but we're predominantly looking at this

294 00:14:59.550 --> 00:15:01.203 in terms of the HVAC system.

295 00:15:02.310 --> 00:15:07.310 So, on the other side here you have air coming in.

296 00:15:07.560 --> 00:15:09.750 So, infiltration is that, what I was talking

297 00:15:09.750 --> 00:15:12.030 about was coming through the cracks.

298 00:15:12.030 --> 00:15:15.120 You have bad windows, ceiling, it's an old building.

299 00:15:15.120 --> 00:15:18.990 You know, there's some areas where air just gets in.

300 00:15:18.990 --> 00:15:21.390 If it's a newer, newer, newer building,

301 00:15:21.390 --> 00:15:23.340 those seals tend to be better and better,

302 00:15:23.340 --> 00:15:24.990 and you have fewer spots for

303 00:15:24.990 --> 00:15:26.733 air to infiltrate from outdoors.

304 00:15:27.810 --> 00:15:28.807 But then you have this,

305 00:15:28.807 --> 00:15:30.300 and you have a penetration factor in there

306 00:15:30.300 --> 00:15:31.440 for how much particles

307 00:15:31.440 --> 00:15:32.880 get through those little cracks.

308 00:15:32.880 --> 00:15:34.750 So they can get stuck on the way.

309 00:15:34.750 --> 00:15:36.413 It's kinda like a filter like our mask.

310 00:15:37.827 --> 00:15:41.010 And you have natural ventilation,

311 00:15:41.010 --> 00:15:43.170 so you open the window because

312 00:15:43.170 --> 00:15:45.930 it's hot out or if you burnt toast,

313 00:15:45.930 --> 00:15:48.480 and that's gonna provide some natural (indistinct).

314 00:15:50.910 --> 00:15:53.340 Indoors, you know, the main thing is

315 00:15:53.340 --> 00:15:55.603 you have emissions for cooking,

316 00:15:55.603 --> 00:15:59.100 you burn a toast or just you know, regular,

317 00:15:59.100 --> 00:16:01.350 you were frying up some eggplant for dinner,

318 00:16:01.350 --> 00:16:04.773 and that generated some PM2.5.

319 00:16:05.732 --> 00:16:08.040 Number of appliances while you're cooking,

320 00:16:08.040 --> 00:16:10.650 actually have a pretty sizable PM sources,

321 00:16:10.650 --> 00:16:12.510 but that depends a lot on cooking style,

322 00:16:12.510 --> 00:16:16.563 and I forget you're affected by some

323 00:16:16.563 --> 00:16:19.053 of the filtration over your stove.

324 00:16:20.149 --> 00:16:21.120 We also worked into the model,

325 00:16:21.120 --> 00:16:23.880 the two loss terms of the deposition of the six.

326 00:16:23.880 --> 00:16:25.890 So, particles go to surfaces and also

327 00:16:25.890 --> 00:16:27.723 they could be meddling outside.

328 00:16:29.550 --> 00:16:32.370 But we're thinking today about,

329 00:16:32.370 --> 00:16:37.200 what is the changes that happen to these terms,

330 00:16:37.200 --> 00:16:40.260 and how it affects the concentrations indoors.

331 00:16:40.260 --> 00:16:44.550 But built within this is thinking about the housing stock.

332 00:16:44.550 --> 00:16:45.750 So Colby Buehler,

333 00:16:45.750 --> 00:16:48.510 a PhD student in environmental engineering,

334 00:16:48.510 --> 00:16:51.179 did a literature view of the US housing stock

335 00:16:51.179 --> 00:16:54.160 working with Peg Long from School of the Environment

336 00:16:55.020 --> 00:16:58.620 to determine the filtration flow rates for

337 00:16:58.620 --> 00:17:01.950 homes' HVAC, and the fraction of homes with HVAC systems

338 00:17:01.950 --> 00:17:04.203 and also the quality of filters in there.

339 00:17:05.250 --> 00:17:07.260 If I was, if we were all talking

340 00:17:07.260 --> 00:17:08.340 about this a couple years ago,

341 00:17:08.340 --> 00:17:11.310 you would probably not be very familiar with the quality of

342 00:17:11.310 --> 00:17:14.040 filters that exists up in these systems.

343 00:17:14.040 --> 00:17:16.560 But there's this whole rating system

344 00:17:16.560 --> 00:17:19.888 for 2, 4, 6, 8, 10, 12, 14

345 00:17:19.888 --> 00:17:23.100 and it goes up to 16, then we get the half a grades,

346 00:17:23.100 --> 00:17:26.190 and that has a major effect on the efficiency

347 00:17:26.190 --> 00:17:30.109 of those filters and the filtration of particles,

348 00:17:30.109 --> 00:17:34.083 doors or air barns, microbes or dusts or anything else.

349 00:17:35.730 --> 00:17:40.620 And then the infiltration and natural ventilation rates

350 00:17:40.620 --> 00:17:44.550 are also affected by house, home aid.

351 00:17:44.550 --> 00:17:46.230 So you think about infiltration,

352 00:17:46.230 --> 00:17:49.110 a home with more cracks, more gaps,

353 00:17:49.110 --> 00:17:54.110 has more infiltration through those penetration points.

354 00:17:57.300 --> 00:18:00.450 Then, the residential energy demand consumption survey

355 00:18:00.450 --> 00:18:04.020 was used to determine appliance usage across all homes.

356 00:18:04.020 --> 00:18:07.860 So, we could look at the distribution in homes.

357 00:18:07.860 --> 00:18:10.650 Obviously, it comes down to how many people live in a home,

358 00:18:10.650 --> 00:18:13.050 but some of us are cooking all the time.

359 00:18:13.050 --> 00:18:14.550 We cook at home every single night,

360 00:18:14.550 --> 00:18:17.460 we use the toaster while we're using the stove,

361 00:18:17.460 --> 00:18:18.927 while we're using the oven.

362 00:18:18.927 --> 00:18:20.940 And some people, you know,

363 00:18:20.940 --> 00:18:25.110 will stop by and, you know,

364 00:18:25.110 --> 00:18:27.210 pick up something from the local

365 00:18:27.210 --> 00:18:29.103 falafel shop for dinner most nights.

366 00:18:32.520 --> 00:18:35.670 So, that's gonna have a huge effect on this admissions term,

367 00:18:35.670 --> 00:18:37.890 and it's going to propagate through this whole system,

368 00:18:37.890 --> 00:18:39.483 as you'll see later.

369 00:18:43.260 --> 00:18:45.600 So we then model over time,

370 00:18:45.600 --> 00:18:48.870 the changes in the US housing stock

371 00:18:48.870 --> 00:18:51.990 up through 2050 for this analysis.

372 00:18:51.990 --> 00:18:55.800 And changes in the building type,

373 00:18:55.800 --> 00:18:58.290 which includes the volume of home,

374 00:18:58.290 --> 00:18:59.790 sizes are going up,

375 00:18:59.790 --> 00:19:03.330 the amount of new homes that are built

376 00:19:03.330 --> 00:19:05.760 and the characteristics of those homes

377 00:19:05.760 --> 00:19:10.620 with respect to the installation of HVAC systems

378 00:19:10.620 --> 00:19:13.590 and filter types and all of that.

379 00:19:13.590 --> 00:19:17.910 So, and ultimately, the big effect that this

380 00:19:17.910 --> 00:19:20.970 has with the changes in the housing stock

381 00:19:20.970 --> 00:19:23.580 and energy creation or energy efficiency

382 00:19:23.580 --> 00:19:26.583 scenario is on this infiltration.

383 00:19:28.350 --> 00:19:30.180 So, how much ventilation occurs

384 00:19:30.180 --> 00:19:34.560 in your home without you actively doing that.

385 00:19:34.560 --> 00:19:37.710 You didn't turn on the HVAC system,

386 00:19:37.710 --> 00:19:39.720 you didn't necessarily open the window,

387 00:19:39.720 --> 00:19:42.453 but you have some pressure changes in home,

388 00:19:43.350 --> 00:19:44.880 and air is also very good

389 00:19:44.880 --> 00:19:47.460 at moving through cracks and things,

390 00:19:47.460 --> 00:19:49.983 and it will bring (indistinct) with it.

391 00:19:51.510 --> 00:19:53.280 If any of you just moved to New Haven,

392 00:19:53.280 --> 00:19:55.923 wait until a nice cold day,

393 00:19:56.940 --> 00:19:59.430 go stand near a window at an older building,

394 00:19:59.430 --> 00:20:00.810 and you'll certainly feel that

395 00:20:00.810 --> 00:20:03.183 cold air moving through some of those gaps.

396 00:20:04.170 --> 00:20:06.600 I know I had that experience when

397 00:20:06.600 --> 00:20:07.950 I first moved to New Haven.

398 00:20:12.540 --> 00:20:13.980 So, we also look at the changes,

399 00:20:13.980 --> 00:20:18.393 changes in the appliance type throughout the study.

400 00:20:21.660 --> 00:20:23.490 I'm gonna talk about something not,

401 00:20:23.490 --> 00:20:25.650 I won't refer to it as a Monte Carlo analysis

402 00:20:25.650 --> 00:20:28.300 over and over again but I want to make the point that

403 00:20:29.430 --> 00:20:31.833 to constrain the uncertainty in the study,

404 00:20:33.210 --> 00:20:38.210 Colby Buehler ran this a lot, a lot, a lot of times.

405 00:20:38.250 --> 00:20:40.620 Thousands upon thousands, across the entire

406 00:20:40.620 --> 00:20:41.940 US housing stock.

407 00:20:41.940 --> 00:20:43.260 So if you go through and you simulate

408 00:20:43.260 --> 00:20:45.630 a whole bunch of homes with this model,

409 00:20:45.630 --> 00:20:48.780 and you look at all the different conditions you can have,

410 00:20:48.780 --> 00:20:50.790 what is the net outcome of those?

411 00:20:50.790 --> 00:20:52.050 So again, we're not just talking about

412 00:20:52.050 --> 00:20:53.490 one home with one set of conditions,

413 00:20:53.490 --> 00:20:55.030 or a small perturbations that

414 00:20:56.180 --> 00:20:57.210 we will look at one or two things.

415 00:20:57.210 --> 00:20:58.667 But trying to put those all together so

416 00:20:58.667 --> 00:21:02.576 we can show sensitivity to these different features.

417 00:21:02.576 --> 00:21:05.490 So, the HVAC system and what it means for emissions,

418 00:21:05.490 --> 00:21:07.188 and how does infiltration change

419 00:21:07.188 --> 00:21:12.188 with energy efficiency measures, and the age of a home.

420 00:21:16.650 --> 00:21:21.650 So questions before we start moving out to results.

421 00:21:24.930 --> 00:21:28.830 If not, good work, you just got through like lecture five,

422 00:21:28.830 --> 00:21:33.423 or six of my class on box models so that's great.

423 00:21:36.180 --> 00:21:37.710 <v Speaker>We do have a student.</v>

424 00:21:37.710 --> 00:21:39.180 <v Dr. Gentner>Yes.</v>

425 00:21:39.180 --> 00:21:42.647 <v Student>Yeah, I'm just, how confident are</v>

426 00:21:42.647 --> 00:21:45.120 you in modeling how the housing stock group

427 00:21:45.120 --> 00:21:47.940 change also changes in appliance?

428 00:21:47.940 --> 00:21:51.873 Like out to 2050, or did you use different scenarios?

429 00:21:53.229 --> 00:21:57.420 <v Dr. Gentner>So, actually Ken,</v>

430 00:21:57.420 --> 00:21:58.770 I'll let you answer that one.

431 00:21:58.770 --> 00:22:00.494 It's phone a friend time already.

432 00:22:00.494 --> 00:22:03.270 The question was how confident are we in the changes

433 00:22:03.270 --> 00:22:06.297 of the housing stock and appliance shifting over time,

434 00:22:06.297 --> 00:22:09.660 and how are those scenarios, model there,

435 00:22:09.660 --> 00:22:12.840 are there multiple scenarios in the NEMS model?

436 00:22:12.840 --> 00:22:14.340 <v Dr. Gillingham>That's a a great question.</v>

437 00:22:14.340 --> 00:22:16.320 What we do is we use,

438 00:22:16.320 --> 00:22:20.670 so it's built into NEMS and NEMS explicitly

439 00:22:20.670 --> 00:22:23.280 is modeling housing stock changes

440 00:22:23.280 --> 00:22:25.173 based on trends in the past.

441 00:22:26.490 --> 00:22:30.723 We easily could do uncertainty analyses over those numbers.

442 00:22:31.560 --> 00:22:35.280 I think that kind of, main takeaway on that

443 00:22:35.280 --> 00:22:38.520 from my understanding is that those aren't gonna be

444 00:22:38.520 --> 00:22:42.390 the driving forces of our final results

445 00:22:42.390 --> 00:22:44.438 unless you are really dramatically

446 00:22:44.438 --> 00:22:45.990 changing the housing stock.

447 00:22:45.990 --> 00:22:48.990 And I know this from another paper, not this paper.

448 00:22:48.990 --> 00:22:50.610 You'd have to really dramatically change

449 00:22:50.610 --> 00:22:54.270 the kind of core housing stock itself.

450 00:22:54.270 --> 00:22:55.710 And the reason for this is that there's

451 00:22:55.710 --> 00:22:58.020 a lot of inertia in the housing stock.

452 00:22:58.020 --> 00:23:01.710 So, there may be changes in how well it's insulated

453 00:23:01.710 --> 00:23:06.480 and you know, broader retrofits in how they're done.

454 00:23:06.480 --> 00:23:11.130 But the basic stock itself is quite slow moving.

455 00:23:11.130 --> 00:23:14.010 That said, I think you should take anything out to 2050

456 00:23:14.010 --> 00:23:16.263 with a grain of salt, maybe a very large one,

457 00:23:17.520 --> 00:23:21.960 and so I'm not gonna hang my hat on the exact numbers on

458 00:23:21.960 --> 00:23:23.790 the nature of the housing stock,

459 00:23:23.790 --> 00:23:24.660 'cause it's the full nature

460 00:23:24.660 --> 00:23:26.460 of the housing stock that's being modeled.

461 00:23:26.460 --> 00:23:27.570 And I'm not gonna hang my hat on the

462 00:23:27.570 --> 00:23:30.300 full nature of the housing stock in 2050.

463 00:23:30.300 --> 00:23:31.980 But I'm pretty confident that the numbers are gonna be

464 00:23:31.980 --> 00:23:34.890 pretty close to right in 2030, 2035,

465 00:23:34.890 --> 00:23:37.680 in that range and maybe even now out to 2040,

466 00:23:37.680 --> 00:23:38.850 just because of how much inertia

467 00:23:38.850 --> 00:23:40.230 there is in housing stock.

468 00:23:40.230 --> 00:23:43.653 But only a small amount of turnover actually occurs.

469 00:23:45.994 --> 00:23:47.527 <v Student>Just on the second part though,</v>

470 00:23:47.527 --> 00:23:51.183 I'd have to be more concerned about appliance type.

471 00:23:52.350 --> 00:23:53.730 It seems like, you know,

472 00:23:53.730 --> 00:23:55.950 we have possible scenarios of

473 00:23:55.950 --> 00:23:59.250 complete electrification, right, by 2050.

474 00:23:59.250 --> 00:24:02.670 Versus not doing that and still having a substantial

475 00:24:02.670 --> 00:24:05.628 number of gas stoves for example,

476 00:24:05.628 --> 00:24:10.628 would have a large effect on your conclusions.

477 00:24:12.300 --> 00:24:13.977 <v Dr. Gentner>So, the question's on</v>

478 00:24:13.977 --> 00:24:15.327 the changes in appliance tech Ken,

479 00:24:15.327 --> 00:24:19.320 and I'll take a quick shot at it and let you add to it.

480 00:24:19.320 --> 00:24:23.130 But, so that does get discussed in the paper.

481 00:24:23.130 --> 00:24:26.610 We don't include specific perturbations but we talk about

482 00:24:26.610 --> 00:24:30.480 how stoves changing up,

483 00:24:30.480 --> 00:24:34.230 changing to full electrification could affect that.

484 00:24:34.230 --> 00:24:36.213 We get into some really interesting questions

485 00:24:36.213 --> 00:24:38.400 then about where the emissions coming from.

486 00:24:38.400 --> 00:24:41.730 Are they derived from the use of natural gas,

487 00:24:41.730 --> 00:24:44.610 or are they derived from the process itself?

488 00:24:44.610 --> 00:24:48.180 If I, like your toaster is generating PM,

489 00:24:48.180 --> 00:24:49.680 based on what you're doing with it,

490 00:24:49.680 --> 00:24:51.180 not so much based on how much power,

491 00:24:51.180 --> 00:24:53.880 obviously, if it's not a natural gas toaster.

492 00:24:53.880 --> 00:24:56.910 But if we're thinking about a stove,

493 00:24:56.910 --> 00:24:59.010 some fraction of that PM comes

494 00:24:59.010 --> 00:25:01.440 from the actual burn itself.

495 00:25:01.440 --> 00:25:05.160 But if it's a reasonable stove,

496 00:25:05.160 --> 00:25:08.313 the PM is probably coming more from the cooking itself.

497 00:25:09.210 --> 00:25:10.950 And that's a really interesting question,

498 00:25:10.950 --> 00:25:15.370 and one that there was a cool paper

499 00:25:16.440 --> 00:25:19.590 that came out of Stanford looking at the emission rates,

500 00:25:19.590 --> 00:25:20.430 although they were thinking more

501 00:25:20.430 --> 00:25:22.320 about methane in particular,

502 00:25:22.320 --> 00:25:25.020 which is where you have a huge impact on (indistinct).

503 00:25:28.330 --> 00:25:31.620 So, on the climate side is where I think

504 00:25:31.620 --> 00:25:32.880 we can see a large effect of

505 00:25:32.880 --> 00:25:34.730 short lived climate pollutants there.

506 00:25:36.750 --> 00:25:41.158 And we do build in a few scenarios

507 00:25:41.158 --> 00:25:43.373 in there to look at some of these changes

508 00:25:43.373 --> 00:25:44.883 and try to bound them.

509 00:25:45.960 --> 00:25:48.180 Ken, can you grade my response

510 00:25:48.180 --> 00:25:50.100 and add anything to help there?

511 00:25:50.100 --> 00:25:51.420 <v Dr. Gillingham>I liked your response.</v>

512 00:25:51.420 --> 00:25:52.410 I wanna add a few things.

513 00:25:52.410 --> 00:25:54.390 One thing is this paper is explicitly

514 00:25:54.390 --> 00:25:56.940 about improving the efficiency,

515 00:25:56.940 --> 00:26:01.930 given the existing forecasted technologies in NEMS.

516 00:26:03.480 --> 00:26:06.810 In our scenarios, it's not about fuel switching,

517 00:26:06.810 --> 00:26:08.430 and I think fuel switching is a really,

518 00:26:08.430 --> 00:26:12.030 really important question and we actually have work underway

519 00:26:12.030 --> 00:26:15.780 to explore that question, where we're looking at scenarios

520 00:26:15.780 --> 00:26:17.580 that actually would allow fuel switching.

521 00:26:17.580 --> 00:26:22.290 So, say switching from burning natural gas in your range,

522 00:26:22.290 --> 00:26:26.430 to an induction range, right? Electric induction range.

523 00:26:26.430 --> 00:26:31.020 So, that type of fuel switching, we hold constant in this.

524 00:26:31.020 --> 00:26:34.320 So we don't, any trends that are in

525 00:26:34.320 --> 00:26:36.273 the baseline in NEMS, we continue,

526 00:26:37.131 --> 00:26:38.040 and we don't focus on those,

527 00:26:38.040 --> 00:26:42.390 our scenarios are very much about improving the efficiency.

528 00:26:42.390 --> 00:26:43.650 I think in reality,

529 00:26:43.650 --> 00:26:45.780 you may end up seeing both

530 00:26:45.780 --> 00:26:48.387 happening somewhat at the same time.

531 00:26:48.387 --> 00:26:50.940 But it depends on the policy direction.

532 00:26:50.940 --> 00:26:53.100 You could see a world in which you do see a lot of fuel

533 00:26:53.100 --> 00:26:55.980 switching and not much efficiency or vice versa.

534 00:26:55.980 --> 00:26:58.680 And I think from a intellectual perspective

535 00:26:58.680 --> 00:27:01.020 it's really helpful to parse those out,

536 00:27:01.020 --> 00:27:03.150 and understand them separately.

537 00:27:03.150 --> 00:27:04.650 So that was sort of the,

538 00:27:04.650 --> 00:27:06.273 some of the thinking behind it,

539 00:27:07.410 --> 00:27:12.210 how it plays out in what we do here in this analysis.

540 00:27:12.210 --> 00:27:13.450 But it's a really great question

541 00:27:13.450 --> 00:27:14.880 and a really important point.

542 00:27:14.880 --> 00:27:17.580 I think it's becoming increasingly important as we move

543 00:27:17.580 --> 00:27:22.500 forward because of the IRA, you know, the recent act,

544 00:27:22.500 --> 00:27:26.940 and other efforts to lead to electrifying the home.

545 00:27:26.940 --> 00:27:31.080 There's been a real push in that direction, so I think,

546 00:27:31.080 --> 00:27:33.810 but this framework that we've set up is reasonably

547 00:27:33.810 --> 00:27:37.099 well suited with some modifications to understanding

548 00:27:37.099 --> 00:27:39.549 the implications of some of those questions, too.

549 00:27:41.820 --> 00:27:44.160 <v Dr. Gentner>Right, thank you for the questions.</v>

550 00:27:44.160 --> 00:27:47.010 Just so I don't have to skip slides at the end,

551 00:27:47.010 --> 00:27:48.900 I'm gonna move forward.

552 00:27:48.900 --> 00:27:51.330 Johan, to answer your question,

553 00:27:51.330 --> 00:27:53.790 the exact materials that are used to change

554 00:27:53.790 --> 00:27:56.010 the building efficiency in terms of insulation

555 00:27:56.010 --> 00:27:57.960 are not explicitly worked in here,

556 00:27:57.960 --> 00:28:02.220 but they are part of changes in building shell efficiency.

557 00:28:02.220 --> 00:28:04.410 So we look at, in the paper we discussed,

558 00:28:04.410 --> 00:28:06.090 how changes in installation versus

559 00:28:06.090 --> 00:28:07.920 changes in building ceiling

560 00:28:07.920 --> 00:28:11.310 could affect the ultimate outcome.

561 00:28:11.310 --> 00:28:15.030 Alright, so, participation time.

562 00:28:15.030 --> 00:28:17.610 How many people in the room have an

563 00:28:17.610 --> 00:28:20.373 HVAC system in their home or apartment?

564 00:28:22.704 --> 00:28:24.054 Alrighty, so we're talking,

565 00:28:25.440 --> 00:28:27.990 alright so that number came in at about 10%.

566 00:28:27.990 --> 00:28:30.030 I don't know, hands were really kind of low on there.

567 00:28:30.030 --> 00:28:32.370 So, now is where we have like,

568 00:28:32.370 --> 00:28:35.400 a choose your own adventure moment in the presentation.

569 00:28:35.400 --> 00:28:40.350 So for those who are in homes that do not have,

570 00:28:43.050 --> 00:28:45.843 it's gonna come back I promise. Alright.

571 00:28:48.180 --> 00:28:50.220 Recirculation with filtration,

572 00:28:50.220 --> 00:28:51.720 here are the overall results for

573 00:28:51.720 --> 00:28:53.793 the entire US housing stock,

574 00:28:54.660 --> 00:28:57.120 comparing the reference scenario

575 00:28:57.120 --> 00:28:59.610 here in the reddish orange color

576 00:28:59.610 --> 00:29:02.100 to the intermediate case in blue.

577 00:29:02.100 --> 00:29:04.230 And then green is the optimistic energy

578 00:29:04.230 --> 00:29:06.030 efficiency case for buildings.

579 00:29:06.030 --> 00:29:08.097 On the bottom here, you're looking at

580 00:29:08.097 --> 00:29:11.010 the indoor emissions percentile.

581 00:29:11.010 --> 00:29:13.023 So the far left,

582 00:29:14.310 --> 00:29:15.690 this is the person who picked up

583 00:29:15.690 --> 00:29:18.514 falafel for dinner every night then.

584 00:29:18.514 --> 00:29:21.750 Hopefully, they got different toppings but they

585 00:29:21.750 --> 00:29:24.270 did not do much cooking in their home,

586 00:29:24.270 --> 00:29:27.180 and breakfast they got on the way to campus.

587 00:29:27.180 --> 00:29:28.290 And on the far right here,

588 00:29:28.290 --> 00:29:31.170 this is the person who wanted deep fried cauliflower

589 00:29:31.170 --> 00:29:36.030 three times times that week, and is cooking a lot.

590 00:29:36.030 --> 00:29:37.560 Maybe it wasn't deep fried cauliflower,

591 00:29:37.560 --> 00:29:38.730 but you get the point.

592 00:29:38.730 --> 00:29:40.950 Here is where there's a lot more indoor emissions.

593 00:29:40.950 --> 00:29:44.190 So it's what you could imagine a home that is,

594 00:29:44.190 --> 00:29:48.690 has more PM generated from various appliances,

595 00:29:48.690 --> 00:29:51.167 but ends up being an an important one,

596 00:29:51.167 --> 00:29:52.380 And on the far left,

597 00:29:52.380 --> 00:29:54.540 this one you can think as a cleaner home

598 00:29:54.540 --> 00:29:56.280 just in terms of the indoor emissions.

599 00:29:56.280 --> 00:29:59.163 So, if you're all the way here on the left side,

600 00:30:00.360 --> 00:30:03.750 you're seeing actually a benefit

601 00:30:03.750 --> 00:30:08.670 compared to the reference case of building tighten.

602 00:30:08.670 --> 00:30:11.910 So reducing that infiltration actually yields you a benefit.

603 00:30:11.910 --> 00:30:16.350 And the reason is, any of the PM that is outside

604 00:30:16.350 --> 00:30:20.940 is not making it indoors because your home is sealed off.

605 00:30:20.940 --> 00:30:23.670 You have a very, you have a tighter box that you live in.

606 00:30:23.670 --> 00:30:25.557 So you are just living with your own emissions,

607 00:30:25.557 --> 00:30:26.700 and you don't have as much

608 00:30:26.700 --> 00:30:29.280 infiltration of particles from outside.

609 00:30:29.280 --> 00:30:32.310 If you move to this other side here,

610 00:30:32.310 --> 00:30:35.403 and you can see where it is worse than the,

611 00:30:36.720 --> 00:30:38.880 oh excuse me, this is with recirculation.

612 00:30:38.880 --> 00:30:40.050 I said before this is without,

613 00:30:40.050 --> 00:30:42.513 this for the 10% of you that have an HVAC system.

614 00:30:45.120 --> 00:30:48.180 Here on this side is showing

615 00:30:48.180 --> 00:30:49.950 if you're doing a lot of cooking indoors,

616 00:30:49.950 --> 00:30:52.110 you actually see a penalty from

617 00:30:52.110 --> 00:30:54.030 those energy efficiency measures.

618 00:30:54.030 --> 00:30:56.760 'Cause now you have bottled up your home,

619 00:30:56.760 --> 00:30:58.350 you have filled all the cracks,

620 00:30:58.350 --> 00:31:02.500 maybe not every last one of them but you haven't improved

621 00:31:03.660 --> 00:31:06.480 the ceiling through your home to the point that you

622 00:31:06.480 --> 00:31:10.113 spend a longer time with any of your emissions indoors.

623 00:31:12.000 --> 00:31:14.910 So, the bummer is that that toast

624 00:31:14.910 --> 00:31:18.210 that you burnt lingers longer,

625 00:31:18.210 --> 00:31:21.027 or any other combustion source that you have indoors.

626 00:31:21.027 --> 00:31:24.757 And so, thus you would have more exposure to that.

627 00:31:24.757 --> 00:31:27.150 Or it could be a continued source of something,

628 00:31:27.150 --> 00:31:28.950 if you had a bad pilot light or something

629 00:31:28.950 --> 00:31:33.950 else in your home then that continues, or persists along.

630 00:31:34.500 --> 00:31:38.610 So, when you're looking at this,

631 00:31:38.610 --> 00:31:42.300 the reference case models the building stock without

632 00:31:42.300 --> 00:31:45.060 any changes from the energy efficiency scenario.

633 00:31:45.060 --> 00:31:46.290 So what is the current inertia,

634 00:31:46.290 --> 00:31:47.520 and everything that we talked about.

635 00:31:47.520 --> 00:31:50.970 And then this represents the change,

636 00:31:50.970 --> 00:31:53.310 where the left shows some benefit,

637 00:31:53.310 --> 00:31:55.560 and the right where you get about

638 00:31:55.560 --> 00:31:58.833 the reference case line shows a detriment indoors.

639 00:32:00.150 --> 00:32:03.840 So, for those of you,

640 00:32:03.840 --> 00:32:07.950 the 90% in the room that don't have an HVAC system,

641 00:32:07.950 --> 00:32:10.503 or other recirculation with filtration,

642 00:32:11.517 --> 00:32:13.230 this is what it looks like.

643 00:32:13.230 --> 00:32:15.060 So, everything is the same here.

644 00:32:15.060 --> 00:32:18.990 The only difference is now we're looking at the 38 to 45%

645 00:32:18.990 --> 00:32:22.060 of homes depending on the scenario that have

646 00:32:25.260 --> 00:32:27.750 no filtration or HVAC system at the home.

647 00:32:27.750 --> 00:32:30.480 So, now you can see this effect is exacerbated.

648 00:32:30.480 --> 00:32:34.260 There's a smaller fraction of homes that see a benefit

649 00:32:34.260 --> 00:32:36.630 for their indoor pollution from

650 00:32:36.630 --> 00:32:38.916 these energy efficiency measures,

651 00:32:38.916 --> 00:32:40.470 and a larger fraction that get

652 00:32:40.470 --> 00:32:43.560 greater exposure to particulate matter,

653 00:32:43.560 --> 00:32:46.287 because they spend more time with those emissions.

654 00:32:47.160 --> 00:32:50.130 So this shows two things,

655 00:32:50.130 --> 00:32:52.810 the importance of the indoor emissions

656 00:32:53.880 --> 00:32:55.630 in determining your indoor exposure

657 00:32:56.580 --> 00:32:58.950 and target ventilation there.

658 00:32:58.950 --> 00:33:00.660 And the importance of recirculation

659 00:33:00.660 --> 00:33:03.110 with filtration, just for PM2.5. Yes?

660 00:33:04.920 --> 00:33:06.450 <v Student 2>This might be a silly question, but,</v>

661 00:33:06.450 --> 00:33:09.780 is there, is like the,

662 00:33:09.780 --> 00:33:11.100 it's hard for me to to believe,

663 00:33:11.100 --> 00:33:14.670 to understand how building efficiency,

664 00:33:14.670 --> 00:33:17.160 have that much impact over HVAC.

665 00:33:17.160 --> 00:33:21.720 Like I would think that homes have the circulation system

666 00:33:21.720 --> 00:33:25.770 would be filtering air more than like,

667 00:33:25.770 --> 00:33:26.940 having cracks in the wall,

668 00:33:26.940 --> 00:33:29.960 and like, not as great of efficiency

669 00:33:29.960 --> 00:33:32.714 would like, have an impact on this.

670 00:33:32.714 --> 00:33:33.547 Does that make sense?

671 00:33:33.547 --> 00:33:35.700 Like, just looking at the reference line there.

672 00:33:35.700 --> 00:33:36.690 So like, if there were no

673 00:33:36.690 --> 00:33:38.940 improved efficiency in the building,

674 00:33:38.940 --> 00:33:41.420 you would still be having this kind of like,

675 00:33:41.420 --> 00:33:43.093 being close to the one to one line

676 00:33:43.093 --> 00:33:45.750 if you had a lot of indoor air emissions.

677 00:33:45.750 --> 00:33:50.750 But then, you improved, like how is the HVAC not filtering?

678 00:33:53.850 --> 00:33:54.840 <v Dr. Gentner>Improving?</v>

679 00:33:54.840 --> 00:33:56.130 <v Student 2>Yeah, I guess, or I guess, yeah.</v>

680 00:33:56.130 --> 00:33:59.370 I just think of it as like constantly pulling air out,

681 00:33:59.370 --> 00:34:01.500 and like, pushing fresher air back in.

682 00:34:01.500 --> 00:34:04.800 So that was the, how is the increased

683 00:34:04.800 --> 00:34:08.257 efficiency of a building making that almost worse.

684 00:34:08.257 --> 00:34:09.960 Does that make sense?

685 00:34:09.960 --> 00:34:10.950 <v Dr. Gentner>It does, and it's actually</v>

686 00:34:10.950 --> 00:34:14.793 a great opportunity to make a clarifying point here,

687 00:34:17.321 --> 00:34:21.223 that in the current paradigm of building temperature,

688 00:34:24.030 --> 00:34:27.093 climate control, infiltration, this is a closed one.

689 00:34:27.960 --> 00:34:31.200 Your HVAC system takes air, conditions it,

690 00:34:31.200 --> 00:34:34.140 and puts it back into your home.

691 00:34:34.140 --> 00:34:36.570 So, it comes down to the efficiency of that filter,

692 00:34:36.570 --> 00:34:39.180 rather than if saying, we're gonna give you

693 00:34:39.180 --> 00:34:41.070 completely fresh air from outside,

694 00:34:41.070 --> 00:34:42.619 to get rid of all our air

695 00:34:42.619 --> 00:34:44.777 from the inside and put it outdoors.

696 00:34:44.777 --> 00:34:47.430 This is where we're starting.

697 00:34:47.430 --> 00:34:50.030 We'd be thinking about like, next generation things.

698 00:34:50.910 --> 00:34:55.110 Is there any opportunities to get fresh air while

699 00:34:55.110 --> 00:34:57.430 not paying the penalty for having to completely

700 00:34:57.430 --> 00:34:59.760 recondition, well I say recondition,

701 00:34:59.760 --> 00:35:03.150 I mean, change the temperature of all the air coming in.

702 00:35:03.150 --> 00:35:04.050 <v Student>Perfect, yeah.</v>

703 00:35:04.050 --> 00:35:06.330 <v Dr. Gentner>No problem, that's a good point to clarify,</v>

704 00:35:06.330 --> 00:35:07.163 so thank you for that.

705 00:35:07.163 --> 00:35:12.163 The only major everyday example for a lot of us,

706 00:35:12.720 --> 00:35:15.990 or exemption to that would be in some of our labs,

707 00:35:15.990 --> 00:35:17.340 we have a fume hood obviously,

708 00:35:17.340 --> 00:35:20.090 we'd dump all of that out the building,

709 00:35:20.090 --> 00:35:21.867 we don't recirculate that.

710 00:35:21.867 --> 00:35:26.820 And there were some changes in various buildings,

711 00:35:26.820 --> 00:35:29.610 like on campus I know where the percentage of fresh air

712 00:35:29.610 --> 00:35:33.093 versus recycled air has changed over the past couple years.

713 00:35:34.800 --> 00:35:39.637 So, alright, so,

714 00:35:43.002 --> 00:35:44.681 If we think about this effect,

715 00:35:44.681 --> 00:35:47.430 this is looking at the overall effect,

716 00:35:47.430 --> 00:35:51.900 the entire housing stock for these two cases,

717 00:35:51.900 --> 00:35:56.580 or two types of homes across old and existing.

718 00:35:56.580 --> 00:35:59.520 Then we have this result where we end up

719 00:35:59.520 --> 00:36:02.760 at steady state having higher overall concentrations.

720 00:36:02.760 --> 00:36:05.010 If you wanna visualize this more,

721 00:36:05.010 --> 00:36:07.590 as what's happening for any singular event,

722 00:36:07.590 --> 00:36:11.100 you can think about the response time to something.

723 00:36:11.100 --> 00:36:14.100 So if you just look at this as a singular case,

724 00:36:14.100 --> 00:36:15.270 let's say here,

725 00:36:15.270 --> 00:36:19.593 you, oh, stick with the burning toast scenario,

726 00:36:20.430 --> 00:36:22.620 you burnt toast or you were frying something,

727 00:36:22.620 --> 00:36:23.820 you generated really high concentrations

728 00:36:23.820 --> 00:36:25.263 and then you stopped.

729 00:36:26.280 --> 00:36:29.215 How long does that take to decay down?

730 00:36:29.215 --> 00:36:32.400 And specifically, we think about that as the folding time,

731 00:36:32.400 --> 00:36:37.400 so down to one over just 37%, to keep it going on.

732 00:36:39.743 --> 00:36:42.750 And, so we look at that in the different scenarios

733 00:36:42.750 --> 00:36:45.450 with and without filtration.

734 00:36:45.450 --> 00:36:46.920 One other point, actually I wanted to make

735 00:36:46.920 --> 00:36:48.540 about your quick filtration question

736 00:36:48.540 --> 00:36:52.170 is in a lot of homes,

737 00:36:52.170 --> 00:36:54.870 we're not recirculating air

738 00:36:54.870 --> 00:36:56.477 at a range of like, the entire house

739 00:36:56.477 --> 00:36:59.523 over 6 points or something.

740 00:37:01.170 --> 00:37:03.510 During COVID we increased some of

741 00:37:03.510 --> 00:37:05.730 those ventilation rates for public spaces.

742 00:37:05.730 --> 00:37:09.270 Marketing air exchange rate of 4 or 5,

743 00:37:09.270 --> 00:37:10.740 those are probably the goal ones.

744 00:37:10.740 --> 00:37:12.213 So air exchange per hour,

745 00:37:13.290 --> 00:37:15.093 but we're not changing everything.

746 00:37:17.190 --> 00:37:19.350 <v ->So, that's why there are differences</v>

747 00:37:19.350 --> 00:37:21.900 here with the filtration and recirculation

748 00:37:21.900 --> 00:37:24.210 for dropping it quicker,

749 00:37:24.210 --> 00:37:26.430 in the cases of having an HVAC system.

750 00:37:26.430 --> 00:37:28.650 And then you can see, you know,

751 00:37:28.650 --> 00:37:30.287 as we tighten up the building more and more

752 00:37:30.287 --> 00:37:33.691 in the optimistic energy efficiency case,

753 00:37:33.691 --> 00:37:37.710 you know, that time that you're spent with the burning

754 00:37:37.710 --> 00:37:39.993 of be it toast or whatever else,

755 00:37:41.456 --> 00:37:44.430 that happen indoors increases,

756 00:37:44.430 --> 00:37:48.074 and you can see the theory we're approaching.

757 00:37:48.074 --> 00:37:50.574 (indistinct)

758 00:37:52.748 --> 00:37:55.440 So, that helps to visualize what's happening,

759 00:37:55.440 --> 00:37:57.240 just in terms of the time.

760 00:37:57.240 --> 00:37:59.364 Hopefully, that's a useful comparison.

761 00:37:59.364 --> 00:38:03.480 <v ->So, but we know that the system</v>

762 00:38:03.480 --> 00:38:06.720 is sensitive to outdoor PM concentration.

763 00:38:06.720 --> 00:38:08.170 So, we did all this modeling,

764 00:38:09.030 --> 00:38:11.790 and then we did a couple case studies

765 00:38:11.790 --> 00:38:16.080 within it across all different outdoor PM concentrations,

766 00:38:16.080 --> 00:38:21.080 and looked at how the system responded to outdoor PM.

767 00:38:22.830 --> 00:38:24.750 Because if we go back to that box funnel,

768 00:38:24.750 --> 00:38:27.600 and I won't put it back on the screen again,

769 00:38:27.600 --> 00:38:28.433 but you know, remember we have

770 00:38:28.433 --> 00:38:30.810 the concentrations of PM outside,

771 00:38:30.810 --> 00:38:31.860 and that's trying to come in

772 00:38:31.860 --> 00:38:34.170 and then we have our indoor PM and that's going out.

773 00:38:34.170 --> 00:38:36.540 So we have this really complex game

774 00:38:36.540 --> 00:38:38.290 that's happening over the building.

775 00:38:39.180 --> 00:38:43.470 And so, if we keep our indoor emissions on the bottom.

776 00:38:43.470 --> 00:38:45.780 So, again, this is the home of the most indoor emissions

777 00:38:45.780 --> 00:38:47.760 and this is the home of the least,

778 00:38:47.760 --> 00:38:49.320 and we look at the outdoor

779 00:38:49.320 --> 00:38:54.320 concentrations on the Y axis here.

780 00:38:55.170 --> 00:39:00.170 So this is the ambient outdoor PM2.5 concentration.

781 00:39:00.180 --> 00:39:01.740 The national average is here,

782 00:39:01.740 --> 00:39:03.330 the annual standard is here,

783 00:39:03.330 --> 00:39:05.703 and then the 24 hour standard's up there.

784 00:39:06.960 --> 00:39:08.100 So, depending on where you live,

785 00:39:08.100 --> 00:39:11.397 and even time of year or if it's a pollution event,

786 00:39:11.397 --> 00:39:14.163 you're going to fall on different spots.

787 00:39:15.810 --> 00:39:19.830 This graph vertically and that ratio of what it is

788 00:39:19.830 --> 00:39:22.410 in the optimistic energy efficiency case,

789 00:39:22.410 --> 00:39:25.740 versus the reference case is shown here.

790 00:39:25.740 --> 00:39:29.760 Where red has just energy efficiency measure

791 00:39:29.760 --> 00:39:34.140 increasing the indoor concentrations,

792 00:39:34.140 --> 00:39:39.140 and blue shows it decreasing the indoor concentrations.

793 00:39:40.950 --> 00:39:43.170 And that's just because again,

794 00:39:43.170 --> 00:39:48.170 here you are preventing the PM from outdoors coming in.

795 00:39:48.930 --> 00:39:51.960 Imagine it's a wildfire scenario,

796 00:39:51.960 --> 00:39:55.015 and you know, you're living in the northwest

797 00:39:55.015 --> 00:39:58.650 and your home is really tightly sealed,

798 00:39:58.650 --> 00:40:01.113 so your concentrations are really high outdoors,

799 00:40:02.220 --> 00:40:03.484 and you're up in this space where your home

800 00:40:03.484 --> 00:40:05.883 is more well sealed so less stuff gets in.

801 00:40:06.780 --> 00:40:08.738 If you go all the way to the right of this

802 00:40:08.738 --> 00:40:10.800 and you're in cleaner conditions outdoors,

803 00:40:10.800 --> 00:40:14.040 but you have a lot of indoor sources,

804 00:40:14.040 --> 00:40:17.940 now that tighter building with with less infiltration

805 00:40:17.940 --> 00:40:20.013 actually increases your indoor content.

806 00:40:21.120 --> 00:40:24.960 So point says, interesting interplay between outdoor

807 00:40:24.960 --> 00:40:29.100 and indoor PM and how that interacts.

808 00:40:29.100 --> 00:40:31.550 So, if there's anything you take away from today,

809 00:40:32.700 --> 00:40:34.170 whether it be for particulate matter

810 00:40:34.170 --> 00:40:38.340 or other atmospheric public health considerations,

811 00:40:38.340 --> 00:40:40.920 I hope it's thinking a little bit about that

812 00:40:40.920 --> 00:40:43.282 interaction between outdoor and indoors.

813 00:40:43.282 --> 00:40:48.282 So, in summary for this slide,

814 00:40:48.960 --> 00:40:51.960 which it literally has a lot of different

815 00:40:51.960 --> 00:40:53.970 information on it and colors.

816 00:40:53.970 --> 00:40:55.980 The impacts of these energy efficiency measures

817 00:40:55.980 --> 00:40:59.100 on indoor air quality are partially dependent

818 00:40:59.100 --> 00:41:00.990 on outdoor air quality,

819 00:41:00.990 --> 00:41:02.910 in addition to the in-home emissions.

820 00:41:02.910 --> 00:41:06.810 So if you were to translate this to Delhi,

821 00:41:06.810 --> 00:41:09.963 or another city that has higher outdoor concentrations,

822 00:41:10.890 --> 00:41:12.783 have to help how you approach this.

823 00:41:15.130 --> 00:41:16.653 There are some studies that were done,

824 00:41:16.653 --> 00:41:19.690 just looking at a few homes back in Beijing.

825 00:41:22.268 --> 00:41:24.460 And, probably like a decade ago,

826 00:41:24.460 --> 00:41:26.780 (indistinct) at Berkeley looked at the changes

827 00:41:26.780 --> 00:41:31.050 in home infiltration and ceiling and how that actually

828 00:41:31.050 --> 00:41:34.893 affected imperfect air concentrations to outdoor ratios.

829 00:41:36.156 --> 00:41:39.480 So, it does have an impact in other locations,

830 00:41:39.480 --> 00:41:42.130 and it can be different than what we're showing here.

831 00:41:43.740 --> 00:41:48.740 Okay, so to wrap this up and look at it together.

832 00:41:50.070 --> 00:41:52.140 I said we wanted to look at the outdoor effects

833 00:41:52.140 --> 00:41:53.070 and the indoor effects.

834 00:41:53.070 --> 00:41:56.883 We spent a little bit more time on the indoor stuff today,

835 00:41:57.930 --> 00:42:00.940 but we get this huge gain

836 00:42:02.040 --> 00:42:05.640 from the reduction in outdoor PM2.5.

837 00:42:05.640 --> 00:42:08.240 This is really like the energy related PM2.5.

838 00:42:09.390 --> 00:42:13.170 So we've dropped the energy demand for buildings

839 00:42:13.170 --> 00:42:16.710 considerably with the cases here.

840 00:42:16.710 --> 00:42:19.773 So intermediate, optimistic, optimistic with carbon pricing.

841 00:42:21.060 --> 00:42:24.180 And so we have a few benefits

842 00:42:24.180 --> 00:42:27.903 in reduced premature mortality that's avoided in 2050.

843 00:42:29.940 --> 00:42:33.003 We just talked about the complexity of indoors.

844 00:42:34.170 --> 00:42:39.170 And so overall, we see a detriment indoors

845 00:42:41.790 --> 00:42:45.137 but this is not for every home,

846 00:42:45.137 --> 00:42:46.090 'cause there's many homes that see a

847 00:42:46.090 --> 00:42:50.400 health benefit from the energy efficiency improvements

848 00:42:50.400 --> 00:42:51.723 based on this modeling.

849 00:42:52.590 --> 00:42:54.900 And so it's those high emissions homes,

850 00:42:54.900 --> 00:42:56.940 high indoor emissions homes that

851 00:42:56.940 --> 00:43:00.633 drive the overall effect negative.

852 00:43:01.560 --> 00:43:03.240 So, those graphs that I showed you before

853 00:43:03.240 --> 00:43:08.240 that had the lines across them for HVAC and non-HVAC

854 00:43:08.340 --> 00:43:09.450 were showing that, you know,

855 00:43:09.450 --> 00:43:12.175 there's a fraction of homes that see a detriment

856 00:43:12.175 --> 00:43:16.410 and need to see a benefit from this as well.

857 00:43:16.410 --> 00:43:19.517 But overall, the indoor effect offsets

858 00:43:21.840 --> 00:43:23.966 this positive outdoor effect,

859 00:43:23.966 --> 00:43:25.230 but it's weighted towards a

860 00:43:25.230 --> 00:43:29.160 subset of homes and a subset of the population.

861 00:43:29.160 --> 00:43:32.574 We look at this on net for those three scenarios.

862 00:43:32.574 --> 00:43:36.030 Intermediate, optimistic, optimistic with carbon pricing.

863 00:43:36.030 --> 00:43:39.270 We see that we get a net benefit from energy efficiency

864 00:43:39.270 --> 00:43:42.503 for avoiding premature mortality for PM2.5.

865 00:43:43.500 --> 00:43:46.020 This is stacked on top of all of the benefits

866 00:43:46.020 --> 00:43:49.653 that we get from the reduced climate pollutants.

867 00:43:53.520 --> 00:43:56.250 So, we get a climate benefit in terms

868 00:43:56.250 --> 00:43:59.070 of reduced CO2 emissions,

869 00:43:59.070 --> 00:44:04.070 and we get a benefit in terms of improved public health.

870 00:44:04.920 --> 00:44:07.830 And that's driven by a large decrease

871 00:44:07.830 --> 00:44:10.140 in energy-related pollutant emissions,

872 00:44:10.140 --> 00:44:12.600 and to some degree,

873 00:44:12.600 --> 00:44:16.560 some of the homes that have poor indoor air quality.

874 00:44:16.560 --> 00:44:18.787 But we do see some of the negative effects

875 00:44:18.787 --> 00:44:21.693 on indoor air quality overall.

876 00:44:22.869 --> 00:44:27.217 That's what I said in summary.

877 00:44:27.217 --> 00:44:30.615 And then, we wanted to test how the effect

878 00:44:30.615 --> 00:44:35.615 of HVAC usage or or filtration system's effectiveness.

879 00:44:37.170 --> 00:44:40.710 So, if we look at the case where we actually upgraded

880 00:44:40.710 --> 00:44:44.100 all homes to have 100% good HVAC systems.

881 00:44:44.100 --> 00:44:47.160 So boost that investment up,

882 00:44:47.160 --> 00:44:52.160 actually increases the health benefits that occur.

883 00:44:52.470 --> 00:44:54.646 So, basically if we improve indoor air quality

884 00:44:54.646 --> 00:44:59.560 through improved filtration indoors at PM2.5,

885 00:45:01.290 --> 00:45:04.417 we can achieve a larger benefit there.

886 00:45:07.410 --> 00:45:11.970 This can be put up as a summary.

887 00:45:11.970 --> 00:45:15.150 Here, where reductions in outdoor emissions,

888 00:45:15.150 --> 00:45:20.150 yielding that benefit across the entire building stock.

889 00:45:21.480 --> 00:45:24.273 And, the observed changes indoor air quality,

890 00:45:25.350 --> 00:45:27.750 due to these energy efficiency improvements,

891 00:45:27.750 --> 00:45:29.820 really require us to think about

892 00:45:29.820 --> 00:45:34.820 improvements to our indoor PM2.5 emissions,

893 00:45:35.670 --> 00:45:38.340 the targeted ventilation of those emissions.

894 00:45:38.340 --> 00:45:41.010 So, better ventilation of cooking emissions,

895 00:45:41.010 --> 00:45:43.950 improving the PM2.5 filtration efficiency.

896 00:45:43.950 --> 00:45:46.890 So, upgrade your filters, get better efficiency

897 00:45:46.890 --> 00:45:49.440 for those of you who can.

898 00:45:49.440 --> 00:45:52.650 And then, careful consideration of these energy efficiency

899 00:45:52.650 --> 00:45:57.650 policies and how we look at ventilation in buildings.

900 00:46:00.960 --> 00:46:02.190 And this is yet another time

901 00:46:02.190 --> 00:46:04.627 where I wish I had Jordan Peccia

902 00:46:05.539 --> 00:46:09.240 on the line as well, to make a few comments on that.

903 00:46:09.240 --> 00:46:12.990 Because it is a really interesting, important topic

904 00:46:12.990 --> 00:46:17.610 for how design, building ventilation for quality of life,

905 00:46:17.610 --> 00:46:21.060 wellbeing and thinking about a range of pollutants.

906 00:46:21.060 --> 00:46:23.850 So we present this today in the paper,

907 00:46:23.850 --> 00:46:25.223 through the lens of PM2.5.

908 00:46:26.725 --> 00:46:28.140 And we include some discussions in the paper

909 00:46:28.140 --> 00:46:29.553 about different pollutants,

910 00:46:30.643 --> 00:46:34.560 I think for indoors, and we did it in various amounts,

911 00:46:34.560 --> 00:46:37.920 so that goes through the range of criteria pollutants.

912 00:46:37.920 --> 00:46:39.313 We can even start to think about radon

913 00:46:39.313 --> 00:46:41.887 in some areas of the country.

914 00:46:41.887 --> 00:46:46.560 We can start thinking about disease transmission.

915 00:46:46.560 --> 00:46:48.660 No worries, it has nothing to do with this paper,

916 00:46:48.660 --> 00:46:53.100 but it does come up against the space

917 00:46:53.100 --> 00:46:54.030 where we think a lot about

918 00:46:54.030 --> 00:46:57.663 building design, and filtration and ventilation.

919 00:46:58.740 --> 00:47:03.740 So, looking at these benefits across the country pay.

920 00:47:04.710 --> 00:47:06.450 The graduate student who was working,

921 00:47:06.450 --> 00:47:09.180 sorry, the postdoc who was working on this,

922 00:47:09.180 --> 00:47:14.180 modeled it spatially and across various geographic regions.

923 00:47:14.460 --> 00:47:16.020 And you can see for the intermediate

924 00:47:16.020 --> 00:47:18.210 energy efficiency pace, the optimistic one.

925 00:47:18.210 --> 00:47:20.628 And then when we employ carbon pricing

926 00:47:20.628 --> 00:47:23.225 and carbon pricing with the optimistic

927 00:47:23.225 --> 00:47:27.030 case where the benefits occur.

928 00:47:27.030 --> 00:47:31.020 And these differences come down in many ways

929 00:47:31.020 --> 00:47:32.910 to how power is, generator,

930 00:47:32.910 --> 00:47:34.530 how electricity is generated in

931 00:47:34.530 --> 00:47:37.050 various areas of the country.

932 00:47:37.050 --> 00:47:39.690 So where we see some of the largest

933 00:47:39.690 --> 00:47:42.630 benefits depending on the case.

934 00:47:42.630 --> 00:47:46.343 So, carbon pricing is gonna have a sudden different effect

935 00:47:46.343 --> 00:47:49.680 than on the optimistic case on it's own.

936 00:47:49.680 --> 00:47:51.780 It's going to change the

937 00:47:51.780 --> 00:47:56.243 underlying fuel that we're using for generator outlets.

938 00:47:56.243 --> 00:47:58.277 So, you know, we think about

939 00:47:58.277 --> 00:48:00.570 the midwest and the northeast here,

940 00:48:00.570 --> 00:48:04.674 the types of fuels that we're using for power plants.

941 00:48:04.674 --> 00:48:07.893 So, using that demand is going have a larger effect,

942 00:48:11.580 --> 00:48:13.780 where there's a higher amount of renewables.

943 00:48:14.700 --> 00:48:17.466 So, in summary, and then we'll open it up to questions

944 00:48:17.466 --> 00:48:19.413 with whatever time we have.

945 00:48:20.370 --> 00:48:22.800 The study used the NEMS model coupled

946 00:48:22.800 --> 00:48:25.027 with The Monte Carlo analysis.

947 00:48:25.027 --> 00:48:26.970 Indoor air quality box model across

948 00:48:26.970 --> 00:48:28.593 the entire US housing stock.

949 00:48:29.430 --> 00:48:33.333 We see a 6 to 11% reduction in carbon dioxide emissions.

950 00:48:34.320 --> 00:48:37.338 and a 18 to 25% reduction in

951 00:48:37.338 --> 00:48:41.670 outdoor energy-related emissions of PM2.5.

952 00:48:41.670 --> 00:48:46.670 So, this is not including other PM2.5 sources.

953 00:48:46.740 --> 00:48:49.140 These reductions are complimentary with carbon pricing.

954 00:48:49.140 --> 00:48:51.660 It takes the pressure off as we're

955 00:48:51.660 --> 00:48:55.320 trying to decarbonize electricity going forward.

956 00:48:55.320 --> 00:48:58.980 So these building event, energy efficiency measures

957 00:48:58.980 --> 00:49:00.870 provide a huge opportunity,

958 00:49:00.870 --> 00:49:05.550 but they require attention to indoor PM2.5 emissions,

959 00:49:05.550 --> 00:49:09.390 and improving PM2.5 filtration,

960 00:49:09.390 --> 00:49:11.293 and thinking about how we implement

961 00:49:11.293 --> 00:49:13.568 these ventilation-grouping policies

962 00:49:13.568 --> 00:49:15.739 that get at some of the nuances that

963 00:49:15.739 --> 00:49:18.000 you're talking about with

964 00:49:18.000 --> 00:49:21.063 fresh air exchange and energy recovery.

965 00:49:23.040 --> 00:49:27.960 And so, in all the majority of homes see improvement

966 00:49:27.960 --> 00:49:30.240 or little change to indoor air quality,

967 00:49:30.240 --> 00:49:32.689 with these energy efficiency improvements.

968 00:49:32.689 --> 00:49:34.352 A subset of homes have increased

969 00:49:34.352 --> 00:49:38.160 PM2.5 concentrations indoors,

970 00:49:38.160 --> 00:49:40.230 which there, overall are driving

971 00:49:40.230 --> 00:49:44.010 health effects going forward there.

972 00:49:44.010 --> 00:49:46.650 And we're seeing that benefit in total, outdoors.

973 00:49:46.650 --> 00:49:51.446 So with that, we are at 12:50,

974 00:49:51.446 --> 00:49:54.360 so I'm happy to take any questions that people have.

975 00:49:54.360 --> 00:49:56.430 I have Ken here to answer all the tough ones

976 00:49:56.430 --> 00:49:58.353 that I can't or don't wanna answer,

977 00:49:59.742 --> 00:50:01.290 and thank you so much for you time

978 00:50:01.290 --> 00:50:02.740 today and for the invitation.

979 00:50:07.232 --> 00:50:09.390 (indistinct)

980 00:50:09.390 --> 00:50:11.517 <v Host>So, I think we have two questions.</v>

981 00:50:11.517 --> 00:50:12.510 <v Dr. Gentner>Okay.</v>

982 00:50:12.510 --> 00:50:13.770 <v Host>I guess each student</v>

983 00:50:13.770 --> 00:50:15.158 already prepared some questions.

984 00:50:15.158 --> 00:50:18.451 So, and what would you want to ask?

985 00:50:18.451 --> 00:50:19.284 <v Student 3>Hey could you go back to</v>

986 00:50:19.284 --> 00:50:21.284 the health impact slide?

987 00:50:23.235 --> 00:50:25.235 Sorry, yeah, thank you.

988 00:50:27.103 --> 00:50:30.120 First, if there was a bar on there

989 00:50:30.120 --> 00:50:34.860 for no, like without the energy efficiency,

990 00:50:34.860 --> 00:50:38.273 like, whereabouts would it be?

991 00:50:41.450 --> 00:50:43.200 <v Dr. Gentner>So this is all comparisons</v>

992 00:50:43.200 --> 00:50:44.910 to the reference case.

993 00:50:44.910 --> 00:50:48.085 So to the current trajector.

994 00:50:48.085 --> 00:50:51.930 So, this is the changes that occur on top of

995 00:50:51.930 --> 00:50:54.930 whatever we expect to happen

996 00:50:54.930 --> 00:50:56.883 in the absence of these standards.

997 00:51:03.464 --> 00:51:08.464 <v Student 3>I guess I didn't consider, (indistinct)</v>

998 00:51:10.432 --> 00:51:12.432 <v Dr. Gentner>It does.</v>

999 00:51:18.010 --> 00:51:22.350 Though, it doesn't include a distribution

1000 00:51:22.350 --> 00:51:25.440 of clients saying you know, across different subsets

1001 00:51:25.440 --> 00:51:30.000 of the population who is spending more or less

1002 00:51:30.000 --> 00:51:31.200 time at their residence.

1003 00:51:33.029 --> 00:51:35.823 But it does scale for them.

1004 00:51:37.193 --> 00:51:40.538 <v Student 4>I was wondering if there are plans</v>

1005 00:51:40.538 --> 00:51:43.007 to put your study off to different groups,

1006 00:51:43.007 --> 00:51:48.007 so looking at how (indistinct)

1007 00:51:53.941 --> 00:51:55.464 You know, what are the,

1008 00:51:55.464 --> 00:52:00.464 are there plans to study the specific (indistinct)?

1009 00:52:02.481 --> 00:52:04.898 (indistinct)

1010 00:52:21.152 --> 00:52:22.638 <v Dr. Gentner>Yeah, so-</v>

1011 00:52:22.638 --> 00:52:26.316 <v Host>The online audience is gonna hear the students-</v>

1012 00:52:26.316 --> 00:52:27.963 <v Dr. Gentner>Oh, okay.</v>

1013 00:52:27.963 --> 00:52:30.428 Yeah the first question, prior to that

1014 00:52:30.428 --> 00:52:34.560 was about the half of the slide that's up.

1015 00:52:34.560 --> 00:52:35.910 What the zero line is, 1016 00:52:35.910 --> 00:52:37.920 and that's the comparison to the reference case.

1017 00:52:37.920 --> 00:52:42.920 The question was just posed is is how much does

1018 00:52:43.140 --> 00:52:45.870 or do we have plans for another study

1019 00:52:45.870 --> 00:52:48.570 or set of studies looking at gas phase pollutants?

1020 00:52:48.570 --> 00:52:52.290 And so we include some commentary in the paper about some of

1021 00:52:52.290 --> 00:52:54.360 the factors that need to be considered.

1022 00:52:54.360 --> 00:52:57.270 And it does, it comes down to how much

1023 00:52:57.270 --> 00:52:58.320 the emissions current indoors

1024 00:52:58.320 --> 00:53:00.030 versus outdoors.

1025 00:53:00.030 --> 00:53:02.580 The other for Nox,

1026 00:53:02.580 --> 00:53:04.410 you already really got out one of

1027 00:53:04.410 --> 00:53:06.933 the huge factors there, is there is no,

1028 00:53:08.520 --> 00:53:10.920 there's not a readily available filter that we already have

1029 00:53:10.920 --> 00:53:13.890 in all the homes that filter NOx with

1030 00:53:13.890 --> 00:53:16.830 the kinda efficacy that we have with particle filters.

1031 00:53:16.830 --> 00:53:21.330 So, that adds a really interesting thing that makes it

1032 00:53:21.330 --> 00:53:23.010 so that HVAC system doesn't have as

1033 00:53:23.010 --> 00:53:25.803 large effect on that gas phase pollutant.

1034 00:53:27.000 --> 00:53:29.370 So, Ken and I have have some things

1035 00:53:29.370 --> 00:53:31.320 that we're thinking about and working on,

1036 00:53:31.320 --> 00:53:35.400 although NOx is not one of 'em at the moment.

1037 00:53:35.400 --> 00:53:38.280 Unless Ken's gonna send me an email later today,

1038 00:53:38.280 --> 00:53:40.200 telling me to start writing.

1039 00:53:40.200 --> 00:53:43.563 But yes, there's a lot of interesting things here.

1040 00:53:44.596 --> 00:53:48.210 Yeah, we're just kinda scratching the surface

1041 00:53:48.210 --> 00:53:49.457 to thinking about how other pollutants

1042 00:53:49.457 --> 00:53:52.200 behave in these changes.

1043 00:53:52.200 --> 00:53:55.500 And Jordan Peccia spends a lot time thinking about moisture,

1044 00:53:55.500 --> 00:53:56.490 and how that's going to affect

1045 00:53:56.490 --> 00:53:58.650 microbial activity at home.

1046 00:53:58.650 --> 00:54:01.440 So we think about holes, and other standpoints.

1047 00:54:01.440 --> 00:54:02.550 That's an area of interest.

1048 00:54:02.550 --> 00:54:05.586 I encourage you to try to catch up with

1049 00:54:05.586 --> 00:54:08.003 Jordan, because he'd love it.

1050 00:54:09.277 --> 00:54:14.027 That is a real important factor on developmental health.

1051 00:54:16.150 --> 00:54:17.607 Great. <v Host>Thank you everybody.</v>

1052 00:54:17.607 --> 00:54:20.700 And because we have across right of us, so we're happy,

1053 00:54:20.700 --> 00:54:22.458 and thank you everyone for coming.

1054 00:54:22.458 --> 00:54:24.227 Thank you again Ken and Drew.

1055 00:54:24.227 --> 00:54:26.376 <v Dr. Gentner>Thank you Ken.</v>