258. MR MOULD QC (DfT): Mr Smart, just two points. The first relates to this question of power usage and the point that was made by Mr Blaine about the greater amount of electricity that would be required in order to power the trains up the gradient as they approach and pass through the Mantles Wood Portal. I just want you, please, to help the Committee in putting that into the context of the relative power requirement for the railway if, rather than at surface from thereon in, it were to proceed in a tunnel until the western boundary of the AONB.

259. MR SMART: Yes. I think what Mr Blaine explained was that because of the gradient there would actually be a power saving that would come out of the proposed longer tunnel. I don't know exactly what calculations he has done, but I can see that if that railway were on the surface then one might be able to extrapolate maybe the power saving that he has suggested, but I think, as the Committee will recall from my presentation on tunnels, it isn't straightforward when you have a train in the tunnel. You have to look at the railway as a whole system, the rolling stock in combination with the tunnel, so it depends on rolling stock factors – the speed of the train, the length of the train, the cross-sectional area of the train, aerodynamic capability, the design of the train – and it also depends on infrastructure factors, such as the size of the tunnel, the portals and cross-sectional area, but I think the two most important factors in all of this are the speed of the train and what we call 'blockage ratio' which is the cross-sectional area of the train in relation to the tunnel. When you put that in a proper modelling system and you look at the tractive effort required under the extended tunnel compared to the Bill tunnel, it results in a four per cent increase in energy required to traverse the Chilterns in the longer tunnel than the shorter tunnel. To give you some kind of perspective of the three key parameters that I've talked about, if you were to increase the size of the tunnel by a metre then you would reduce the increase in tractive effort to about half that, which gives you some idea of the effect of the tunnel that I'm talking about. So in fact the longer tunnel results in an increase in traction power.

260. I think Mr Blaine gave an example of about 6,000 houses that he thought would be saved by the saving in energy. I don't quite know where he got that figure from, but if you were to take typical Ofgem figures for a domestic house – I think they quote 8.7 kWh/day for the average domestic house – the increase in energy equates to about 12,500 kWh per hour. If I were to translate that into a similar sort of example that

Mr Blaine used, that means the extra energy required to go through the longer tunnel would actually power about 25,000 domestic houses. So that's really the difference. It's about looking at the effects of the tunnelling in terms of the air issues that you get and not just the gradient, which is not the dominant factor in a tunnel.

261. SIR PETER BOTTOMLEY: You require less power to go in the open air than you do to go through a tunnel because you're not going to push the air aside?

262. MR SMART: Correct, Sir Peter.

263. SIR PETER BOTTOMLEY: You're saying that the extra length of tunnel outweighs the undoubted greater unevenness of the Promoter's scheme?

264. MR SMART: Yes, significantly. Of course, my example, by saying that if you increase the tunnel size you halve that extra, is that the closer you get to fresh air the better it gets.

265. SIR PETER BOTTOMLEY: Although there was of course the atmospheric railway, where you took all the air out and pulled the train along with suction.

266. MR SMART: I should also say that that is just the traction power. Of course, as the Committee has already heard, in tunnels you require a lot more mechanical and electrical plant and equipment and that also requires power. I think you've also been aware from previous evidence that we do have a problem with cooling – the longer the tunnel goes. When you get above 10 kilometres, you do require active cooling in the tunnels. On a tunnel of this type of length, with seven shafts, we'd probably be putting in 1.5 to 2 mW of cooling at each shaft to keep the temperatures under control.

267. SIR PETER BOTTOMLEY: One of the cases put forward by the petitioners is that having ballastless track in the tunnel makes it easy to monitor its state and makes maintenance cheaper. Is a ballasted track cheaper to install than a track without ballast?

268. MR SMART: Potentially we could use ballasted tracking in cut and cover – what have been called 'green tunnels' but they are cut and cover tunnels. The bored tunnels have concrete slab in them. In terms of your general point, in terms of ballast versus slab, slab is much more expensive to put in, but of course you get the payback on the whole lifecycle cost because you do less maintenance. Ballast is cheaper to put in, but if

you have a heavy tonnage then you have to do a ballast clean and tamp the line to restore the profile of the ballast. It does come with a heavier maintenance burden. So there's a definite trade-off to be played there. Of course if you have ground movements as well, if you have significant cuttings and embankments, which we do have, there's also the question of how you deal with the ground movement in relation to the track profile.

269. SIR PETER BOTTOMLEY: Is it the intention to have ballast on the track in the open air on most of the line or is it too early to say?

270. MR SMART: We've made the decision that in tunnels – I think it's fairly clear that what is bad is having constant transitions between ballast and slab. If you consider the amount of running tunnel and viaduct that we have as we come out of London, subject to detailed design, I'd be very surprised if we weren't on a slab formation all the way until we get out of the Chilterns. When we get out of the Chilterns and into the area going north, where we do have a lot more cuttings and embankments, there is more of a choice to be made between a ballasted track or a slab track. There is still, I think, an optimisation process to look at because there are also the effects on construction. If you get significant ground movement, it's about whether and how you contain that in a slab situation.

271. SIR PETER BOTTOMLEY: Can I ask you one last question? We've been told that you can go at a certain speed in a bored tunnel, at a higher speed in a cut and cover tunnel and potentially a greater speed completely in the open air. Why is the speed in the cut and cover tunnel allowed to be higher, or it would be higher, than in a bored tunnel?

272. MR SMART: Well, it's not necessarily. You still have to have the free air to deal with the pressure, to deal with the phenomenon that I'm talking about, which is the pressure of the air. We have some constraints on coming out of London in terms of the size of the tunnel, but you can design for it. It's just a question of how big you make the cell or how big you make the bore.

273. SIR PETER BOTTOMLEY: Thank you.

274. MR MOULD QC (DfT): Mr Smart, again, could you just pull back a bit in your

chair because Mr Hendrick is looking at your back?

275. MR SMART: Sorry. I do apologise.

276. MR MOULD QC (DfT): Just for reference, I've put on the screen paragraph 5.1.5 from our response report to the Chilterns Long Tunnel, which is in the documents. We don't need to read it out. It summarises the point that you've been making about power needs. The other question I wanted just to confirm with you was the question of security fencing. For that purpose if we can put up, please, slide A1185(3). This was Mr Kirkham's slide. I think you'll recognise this, Mr Smart.

277. MR SMART: It's High Speed 1. I think the Committee might recognise it from a site visit. That's North Downs. So what you have here is that – clearly the railway has to have a security fence. Mr Miller was talking about how you create landscaping and roll the landscaping in. Here, it shows an example that at the top of the cutting you can use a normal type of rural-type fencing, which could be rail and post because this is really just keeping animals out and demarcating the top of the line, and you can put the security fencing, which is typically a wire fence, potentially three metres high – we need to do the detailed design – further down the cutting and much closer to the line side and therefore it isn't intrusive on the landscape. Mr Miller talked about palisade fencing. Depending on where your railway is going, if you are going through urban areas where there's a significant risk of trespass and vandalism and you have more important railway line-side equipment, you might well use palisade fencing, as is used on the national rail network, but certainly in the rural areas this is typically what you will see. I think the Committee will recall that on High Speed 1, as part of economical vegetation management, they actually allow sheep on the line between the security fence and the rural fence at the top of the cutting.

278. MR MOULD QC (DfT): As you see on the reservoir, it's just to the west of –

279. MR SMART: There isn't actually one on that photo unfortunately, but that's a bit closer to the portal.

280. MR MOULD QC (DfT): Whilst we have this in front of us, and I don't say that this is an example of it, just as a matter of interest, what is the steepest gradient that you have?

281. MR SMART: As I think Sir Peter correctly said, 1 in 40 is the steepest gradient.

282. MR MOULD QC (DfT): Thank you very much.

283. MR SMART: Thank you.

284. CHAIR: Mr Straker?

285. MR STRAKER QC: Thank you very much. Can we put back up, please, P7470(33)? This is the passage to which you were referred. In particular, paragraph 5.1.5, as stated in section 4, is within a report which was prepared expressly to contrast and compare the Chilterns Long Tunnel with the at grade scheme, isn't it?

286. MR SMART: Yes.

287. MR STRAKER QC: Yes. Paragraph 5.1.5 appears in a section dealing with construction costs, which one sees from the top.

288. MR SMART: Yes.

289. MR STRAKER QC: Paragraph 5.15 draws on section 4.4 for the proposition that it makes.

290. MR SMART: Yes.

291. MR STRAKER QC: Can we go back to section 4.4, please, on page 7470(28)? This begins at paragraph 4.4.1 and is contained under the heading: 'Traction power and overhead contact system'.

292. MR SMART: Yes.

293. MR STRAKER QC: Paragraph 4.4.1: 'In overall terms, based on comparative single train performance simulation runs for a 400-metre long train…' Just pausing there, that's the estimated length of the conventional HS2 trains?

294. MR SMART: Yes.

295. MR STRAKER QC: '…that have been undertaken…' So those simulation runs will have been done presumably through a computer model?

296. MR SMART: Yes.

297. MR STRAKER QC: '…total train mechanical energies are predicted to be slightly lower for the proposed [Chilterns Long Tunnel] option…'

298. MR SMART: Yes, but it does go on to say: 'However there is predicted to be an appreciable redistribution… of average traction…' This really here was looking at the construction costs of the tunnel. It wasn't necessarily looking at the energy requirements in the way that you have suggested. That has to be done as a separate piece of work.

299. MR STRAKER QC: Well, it says what it says and refers to 'total train mechanical energies'. That phrase there used is used to describe all total mechanical energies associated with the mechanisms of the train. Is that right?

300. MR SMART: Well, it is right, but that comes back to how you're looking at just the gradient if you're in air compared to where you're in tunnels. What needs to be done on top of that, as we have carried out, is a different assessment, if I may say that.

301. MR STRAKER QC: Anyway, that is what was said in the report. If we look, please, at page 47470(27), the preceding page, and paragraph 4.3.1 and what was done on behalf of HS2: 'An assessment [was] undertaken to determine the implications of journey time, technical headway and mechanical traction energy between the Proposed Scheme and the alternative CLT proposal'. So compare and contrast was the exercise undertaken, yes?

302. MR SMART: That's right.

303. MR STRAKER QC: That was in relation to the implications as they are set out, to include mechanical traction energy. If we look over the page, please, at page 47470(28), the authors have set down in tabular form, haven't they, if we go to the top of page 28 please, the various ways down away from London and up to London? We can see there the first two lines across are the HS2 as proposed scheme, but that has the nought value, because one is seeking to see a variance from it, and then 'PBA' is the Chilterns Long Tunnel scheme. The journey time differences are recorded down as three seconds and up as ten seconds.

304. MR SMART: Yes.

305. MR STRAKER QC: Then the technical headway is recorded and then we have the summated journey mechanical energy in kilowatts per hour, is it?

306. MR SMART: Yes.

307. MR STRAKER QC: We can see that there are differences in mechanical energy from baseline favourable in terms of less energy being employed: PBA down is minus 8 and PBA up is minus 190.

308. MR SMART: Yes, but what this is looking at is the actual mechanical and electrical plant that you need to provide the energy to the train. It is not looking at what the train is actually drawing at the pantograph as it goes through the tunnel either accelerating or braking. It's an apples and pears comparison that you're making. You would have to look at a report that actually looks at what happens with the train tractive effort and what it would draw. What this is saying is that in order to extend the Chilterns tunnel we would not need to put in bigger autotransformer stations necessarily and, if you like, make the actual feeder stations larger etc, but what we're looking at is the running costs – as Mr Blaine said, the energy that is required by the train – and it's two different things.

309. MR STRAKER QC: Then if we just go down the page a little bit, please, to paragraph 4.3.4, the authors have added: 'The summated mechanical energy figures show an energy saving over the Baseline due to the tunnel alignment providing [as it does] a flatter profile than the Proposed Scheme. Tunnel resistance is of less impact than gradient in this case. The impact of the mechanical energy figures is discussed in the traction power section'. Pausing there, the authors were well alive, weren't they, to your point about tunnel resistance but expressed openly the point that it was of less impact than gradient in this case?

310. MR SMART: Well, that is because we were looking at the gradient of a tunnel and the analysis that has to look at the other factors was not carried out in relation to a construction report, which is probably why Mr Blaine suggested that there was actually a favourable power benefit, because it's really looking at the gradient. Although it has reported that there are other factors, you in fact need to do a separate piece of analysis to

get that answer.

311. MR STRAKER QC: Do we have that separate report here before the Committee?

312. MR SMART: No, because we didn't consider that you were going to raise that issue, but if you would like us to give you a technical note on why that is the case then that's perfectly possible.

313. MR STRAKER QC: I see. Well, for the moment we have this report which draws attention to the mechanical energy in the way that it does, Mr Smart.

314. MR SMART: That's that report, but as I said you're looking at one side of a two-sided coin.

315. MR STRAKER QC: The purpose of the report, as we've discussed, was because HS2 Limited was aware that we were seriously putting forward the Chilterns Long Tunnel as a viable proposal and wanted to draw a contrast between that and the ground-level scheme.

316. MR SMART: Yes, and the discussions that we'd had and what we were responding to in the report was the construction costs difference between the two schemes. It did touch on other factors, but as I've suggested there's a different analysis that you'd need to look at to get the full picture. If that needs to be made available to address the particular point that I've made then that can be done.

317. MR STRAKER QC: What the Committee has in terms of the material contrasting the mechanical energy and the time in terms of the running of the trains is that table we've just been looking at, isn't it, Mr Smart?

318. MR SMART: Well, that is on the gradient, yes. So we can expand on that and give you a better understanding. There is actually a marginal impact on journey time of about 14 seconds if you extend the tunnel.

319. MR STRAKER QC: Thank you very much, sir.

320. CHAIR: Thank you. Mr Mould?

321. MR MOULD QC (DfT): I have no further questions. Thank you.