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October 29, 2018

VIA EMAIL
28443

Ms. Doreen Friis
Regulatory Affairs Officer/Clerk
Nova Scotia Utility and Review Board
1601 Lower Water Street, 3rd Floor
Halifax, NS B3J 3S3

Dear Ms. Friis:

Re: M08349 – Nova Scotia Power Inc. – CI# 47124 – Advanced Meter Infrastructure (AMI) Project

Please accept this letter and attachment as the Consumer Advocate's comments in relation to NSP's compliance filing of August 31, 2018 that estimated the cost to customers who decide to opt-out and not have an AMI meter installed. NSP forecasts an opt-out charge of $12.21 per month for customers whose meters are read bi-monthly and $24.42 for demand customers whose meters will continue to be read monthly.

The Consumer Advocate requested that Resource Insight review NSP's assumptions and modelling. Resource Insight has concluded that there is a substantial risk that NSP has overstated the costs of opting out by a wide margin.

In addition to the issues highlighted in the attached report, the Consumer Advocate notes that NSP has made no change to meter reading frequency for opt-out customers. At para. 194 of its AMI decision, the Board noted:

> Therefore, the Board finds the customer should be permitted to opt-out and continue with a non standard meter. The Board urges NSPI to consider if there are means by which the costs might be minimized, e.g., by reducing the frequency of readings.

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Based on the compliance filing and subsequent responses to IRs, it does not appear that NSP has thoroughly analyzed the means by which costs might be minimized.

Yours truly,

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WLM:dlb

Enclosure

#249200

Review of NS Power Compliance Filing on its Proposed AMI Opt-Out Charge

Paul Chernick
Ben Griffiths
Resource Insight, Inc.
October 29, 2018

I. Introduction

NS Power is in the process of converting its meters to an Advanced Metering Infrastructure (AMI) system. As part of that process, NS Power has sought to establish an incremental meter-reading charge for customers that opt out of automatic meter reading. In its August 31, 2018 compliance filing on its AMI plan, NS Power provided a simple model that purports to calculate the incremental cost of reading the opt-out meters.

The primary determinants of the AMI opt-out charge are the estimates of travel time from one opt-out customer to the next and meter-reading time, but the model also includes costs associated with customer service and staff supervision. The NS Power model estimates that reading a meter takes five minutes per meter and that travel time between opt-out meters would be 15 minutes in an urban environment and 25 minutes in rural areas. As a result of its assumptions, NS Power estimates that the incremental cost for customers read bi-monthly is $12.21/month and the charge for customers read monthly is $24.42/month. NS Power proposes these incremental charges for opt-out customers.

The values that NS Power uses in its model for travel time and meter-reading time are not well supported and conflict with other available data. Other suspect assumptions, including the assumption that meter-reading positions must be filled by full-time employees, who cannot do other work, are similarly unsupported.

II. Time to read meters

NS Power inputs to its model an estimate that reading each meter takes five minutes, NSP's actual average time per meter read is 1.67 minutes, including travel (CA IR-3(a)). Accordingly, NSP's estimate for the time it takes to read a meter is at least three times longer than what is currently required. If travel time currently averages just 25 seconds (averaging over single-family, multi-family, commercial, urban and rural), read time would be 1.15 minutes and the overstatement rises to a factor of four. If travel time is 40 seconds, read time falls to one minutes and that overstatement rises to a factor of five.

Revising NSP's cost model to reflect the less-overstated read time of 1.67 minutes, but not correcting any other problems, would reduce the bi-monthly read cost, from $12.21/month to $11.01/month. With a read time of one minute, the monthly cost would fall to $10.36/month.

III. Time to travel between meters

Travel time between meters drives the bulk of the opt-out charge. NS Power provides no evidence that its estimates of 15 minutes to travel between urban opt-out meters and 25 minutes to travel between rural opt-out meters are grounded in any relevant data.

The 15 minutes of travel time per urban meter is not a derived value; it is an estimate of the average time between jobs for the purposes of workforce planning. NS Power currently uses an average estimate of 15 minutes of travel time for service orders scheduled in urban markets and currently (year to date) has a 99 percent completion rate on service orders. This indicates that this estimate of average travel time enables a high completion rate of scheduled work orders. (NSPI Response to CA IR-13)[1]

It appears that NS Power is using generic travel-time estimates that are set high to allow employees with scheduled service time to appear on or before the scheduled time, to estimate the time required for meter readers to complete their route. This extrapolation is improper in two respects. First, the service trips are often scheduled to respond to customer requests, and thus cannot be optimized in the same manner as meter-reading, especially for the bi-monthly routes. Second, the 99 percent completion rate metric does not indicate that the estimate is reasonable, but that it is conservatively high. For example, if NS Power estimated that rural travel time between service orders was one hour, but travel took 15 minutes, then the on-time completion rate would be very high, but the estimate would be four times too high.

The NSP model also fails to account for the relationship between travel time and the number of opt-out customers. NSP suggests that if 4% of customers opt out of automatic meter reading compared to 2%, then the man-hours required to read the opt-out meters would double (SBA IR-11 Attachment 1). This claim is obviously flawed. As the number of opt-out customers increase, the average distance between opt-out customers would almost certainly decrease. A simple thought experiments illustrate this point. Using NS Power's logic, if all customers opted out, the time required to travel between meters would increase by 50 times (2% opt out to 100% opt out), total meter reading time would increase to 1.3 million hours per year, and 756 meter-readers would be required. In actuality, NSP only employs 79 meter-readers, one-tenth as many as the NS Power model would predict (CA IR-3). There are obvious economies of density in meter-reading, yet NS Power fails to capture this dynamic in its model.

NS Power estimates that travel and meter-reading times for opt-out be 12 times the current average for urban customers, 18 times for rural customers and 15 times on average. We agree that travel times to serve opt-out customers will increase compared to the *status quo*, because out-out customers will tend to be further apart, and meter reading routes will service fewer meters per kilometer traveled. Based on two separate models, we estimate that average travel time between opt-out customers will be in the range of four to eight minutes per meter, compared

[1] NS Power uses similar language in its discussion of the rural travel times (CA IR-14). NS Power had some difficultly defining "urban" and "rural", the urban areas are limited to some areas in and around Halifax and Sydney (Synapse IR-6(a)).

to NS Power's assumed average of about 19 minutes. This figure is just for travel time, not physically reading the meter.

A. Travel Time Models

Resource Insight developed two different travel time models to empirically assess travel time between opt-out customers. The two models rely on different datasets, and have complementing strengths and weaknesses:

- The "top down" model calculates the time and distance between opt-out customers in each of Nova Scotia's 1643 census blocks, assuming that opt-out customers are evenly spaced within each census block.

- The "bottom-up" model simulates 250 rural meter-reading routes that service opt-out customers located on a main road or adjacent spurs, using data on housing frequency from Google Maps. From these routes, we calculate average travel distance and average travel time between opt-out houses.

The primary advantage of the top-down model is that reflects the variation in population density across the Province. Because there are so many census tracts, some regions have very high population density and others have very low population density. The dataset has population densities ranging from 0.4/km^2 to 50,750/km^2. Regions with high population densities will tend to have lower meter read travel times than the regions with the low population densities. For example, travel distances range from 50 meters to 20 kilometers. The former takes less than a minute to reach while the latter could take 20 minutes or more (depending on average driving speed).

The top-down model has two notable strengths. First, the assumption that customers are evenly spaced within a census tract is dubious: for example, a rural block might include a village where all houses are located and then a great swath of forest. In this case, uniform spacing overstates the distance between customers. Second, the model has a crude approximation of Nova Scotia's road network. It assumes that the meter reader must travel along two sides of a square between each opt-out house and that the meter reader drives a constant speed along the route.

By contrast, the bottom up-model offers a more detailed assessment of driving routes, but at the expense of the regional variability captured by the top-down model. The bottom-up model explicitly models how a road segment in the province may be laid out. It does make some simplifications, for model tractability, but does offer specific driving routes to meet specific simulated opt-out customers. The modeled road topology is more conservative than other possible configurations: if spur roads connect with one another, a meter reader will could service all the opt-out customers on both spurs without back-tracking.

The bottom-up model assumes that rural roads throughout the province follow the same normal distributions we estimated – an assumption that might not be true. It is possible that road segments we did not explore are materially different (either more or less dense) than the segments we identified. One additional shortcoming of the bottom-up model is that it does not estimate urban travel-times. Given the shorter distances between meters in an urban setting, however, the rural estimate can be used as an upper-bound for urban travel time as well.

The top-down and the bottom-up models both have strengths and weaknesses. By design, however, the shortcomings of one are the strengths of the other. When considering results from these two models in tandem, we find that both models offer results in relative agreement with one-another and in stark contrast to the travel time estimates put forth by NSP.

While NS Power could produce a more realistic model from its GIS data on customer locations and its meter-reading routes, it has chosen to provide no analytical results at all. Hence, our simplifications are the best models available at this time.

Details of both models are found in Appendix A.

B. Travel-Time Model Benchmarking

We benchmarked the two models against NS Power's current metering system by assuming that 100% of customers opt-out of AMI. Were all customers to opt out, then meter reading routes would be the same as today and the predicted average travel time could be compared to NSP's reported actual time.

The top-down model indicates that the average travel time between meters would be between 1 and 2 minutes, depending on the assumed travel speed. The lower end of this range is consistent with NS Power reported average time per meter of 1.67 minutes, if the meter-reading time is under 40 seconds. The bottom-up model indicates travel time of 20 to 60 seconds per customer. This estimated time is shorter than that found using the top-down model, but is still roughly in line with the NS Power's actual average of 1.67 minutes per customer for travel and reading, if the reading time is 40 seconds to 1.3 minutes.

C. Travel-Time Model Results

The top-down model indicates that the average travel time between opt-out customers ranges from a little less than 3 minutes/customer up to 7.5 minutes per customer, depending on travel speeds, as shown in Figure 1.

Figure 1: Top-Down Model Average Travel Time (Minutes)

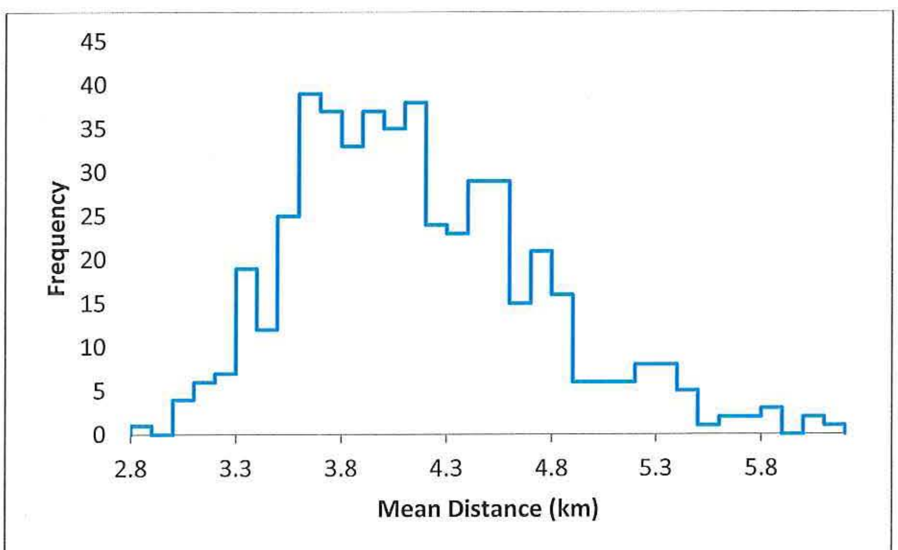
Drive Speed (km/h)	Walk Speed (km/h) 3	3.5	4	4.5	5
20	7.5	7.4	7.3	7.2	7.1
30	5.3	5.2	5.1	5.0	4.9
40	4.3	4.1	4.0	3.9	3.9
50	3.6	3.5	3.4	3.3	3.2
60	3.2	3.0	2.9	2.8	2.8

The median travel time in the range we considered is 4 minutes per customer.

The bottom-up model, simulating rural regions, indicates somewhat longer travel times. Across the 500 Monte Carlo simulations, we find that the average rural travel distance is approximately 4.1 km.

Figure 2 plots a histogram showing the relatively frequency of mean travel distance. The plot indicates that travel distance between opt-out meters is rarely less than 3 km and rarely further than 6 km.

Figure 2: Bottom-Up Model Histogram of Average Travel Distance Between Rural Opt-out Customers



In Figure 3, we calculate implied urban speed by scaling down the rural speed by 60%, to mimic NS Power's 60% ratio of travel times (15 minutes urban, 25 minutes rural). We also computed an implied system average travel time, using NS Power's assumption that 43.6% of customers are rural.

Figure 3: Estimated Travel Time (Minutes, Bottom-up Model)

	Travel Speed (km/h)				
	20	**30**	**40**	**50**	**60**
Rural	12.5	8.3	6.3	5.0	4.2
Implied Urban	7.5	5.0	3.8	3.0	2.5
Implied System	9.7	6.5	4.8	3.9	3.2

Based on the median distance estimate and a travel speed of 60 km/h, expected travel times would equal 4.2 minutes per rural opt-out customer. Assuming a slower 40 km/h travel speed, average travel time would equal 6.3 minutes per customer.[2] This range of travel times estimates is higher than the results of our top-down model, but just 20% to 33% of NS Power's rural travel-time assumption.

Despite the very different nature of these two models, their results show relatively good agreement. The average travel time of the top-down model is 4 minutes per meter and the average travel time in the bottom-up model is also about 4 minutes per meter.

[2] These speeds would reflect higher travel speeds on rural highways (90 km/h) and rural local roads (80 km/h), with lower speeds in villages (perhaps 50 km/h), as well as an allowance for slow vehicles, turning and crossing traffic, getting in and out of the car, and the like.

IV. Cost Estimates using Revised Travel & Read Times

NS Power overstated and unsubstantiated time estimates significantly increase costs to opt-out customers. Using the NS Power model as our starting-point, we estimate the bi-monthly reader charge using the travel-time and meter-reading time estimates derived in the preceding sections. More specifically, we set read time to the thirty seconds estimated in CA IR-3 Attachment 2 page 5, one minute, and (for comparison) NSP's proposed 5-minute figure and we vary average travel times from 4 to 7 minutes.[3] Results are depicted in Figure 4.

Figure 4: Incremental Cost of Opt-Out for Bimonthly Readings ($/Month), NSP Model

Times in Minutes				
Reading	**Travel Between Opt-Out Meters**			
	4	**5**	**6**	**7**
0.5	$4.51	$4.51	$5.16	$5.68
1	$4.51	$5.16	$5.68	$5.68
5	$6.21	$6.86	$6.86	$7.51

Figure 4 shows that the cost for bimonthly reads would be in the range of $4.51/month to $5.68/month, assuming the plausible meter-reading time estimates, even without correcting any other NS Power errors. These empirically based results are 50% to 60% lower than NS Power's requested charge.

Using NS Power's simplifying assumptions, charges for monthly-read customers would be twice the bi-monthly rates. It is likely that the monthly customers would be more spread out and more expensive to read, both currently and as opt-out customers. NS Power has not addressed the additional cost of reading meters for these large customers. It is not clear whether any of the large monthly-read customers will opt out, so the pricing of opt-out monthly customers may not matter.

[3] We also fixed NS Power's spreadsheet, which set the number of MRs at 8, rather than the number of urban meter readers, which was apparently NS Power's intent (CA IR-16).

V. NS Power's Rationale for its Time Estimates

While NS Power does not offer any derivation of its time estimates, it does offer some defense of the reasonableness of its estimates, including the following.

CA IR-3 Attachment 2 provides a rather atypical example to attempt to reconcile its total assumed 20 minutes for an urban opt-out read with the current 1.67 minutes. The example uses two apartment buildings, each with over 100 units example, far enough apart to require the meter reader to drive, for which the meter reader does not have keys to the meter rooms and where each superintendent takes 15 minutes to produce the key.[4] Apartments in any size buildings were only about 23% of the Nova Scotia housing stock in 2015.[5] Apartments in buildings large enough to require meter rooms are an even smaller part of the stock.[6]

Normally, a "Meter Reader acquires a 'key ring' for the routes to be covered for the day that will enable inside meter access." (CA IR-2, Step 2) NS Power assumes that these particular superintendents will not allow NS Power to have keys, will not leave the keys at the front desk for the meter readers, and cannot be alerted that the meter reader is on the way. If the meter reader just needs to pick up and return the key to the superintendent, the time would fall from 18.5 minutes to 9.8 minutes; if the keys are on the meter reader's ring, the time drops to 7.2 minutes.

NS Power also assumes that, of the 264 customers in the two buildings, only 3, rather than the expected 5 or 6, opt out. Assuming independence in the distribution of opt-out customers, there is a 12% chance of 3 opt-outs, and 12% for 7 opt-outs, with higher probabilities for 4, 5, or 6 opt-outs (17%, 18% and 16%, respectively). With 7 opt-outs, the time per meter would fall from 18.5 minutes to 8.2 minutes. There would also be a 14% chance that one of the two buildings would have no opt-outs, cutting the time dramatically.

Combining the adjustments for NS Power did not construct a worst-case scenario for this example, but it came close.

CA IR-3 Attachment 1 asserts that meter-readers would need to travel past every customer to reach the 2% that opt out. "On average a ~2% opt-out rate means 1 Opt Out customer for every 50 premises passed with no alignment of bill cycle." (p. 1) We discuss the fact that the meter readers would be able to skip about half rural side roads entirely and drive only a portion of almost all the others in Appendix 1, Section C. For an urban or suburban grid of mostly single-family homes, the meter readers would typically need to travel only a fraction of the streets. For example, Fairview is mostly a grid 4 wide blocks wide and nine short blocks high, with about 12–15 customers on each of the long blocks and only a handful on the short cross-streets. Visiting all of the meters would require traveling up each of the long blocks twice (once for each

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[4] NS Power also added the number of out-out meters to the total times on CA IR-3 Attachment 2, page 6; correcting this error drops the average time in NS Power's example from 19.5 minutes to 18.5 minutes.

[5] http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=ns.

[6] About ⅔ of the apartments in the Halifax CAM are under five storeys.

side of the street) and up at least eight of the short blocks (and perhaps a bit more, to reach the few houses facing the side streets). Only about half of the long blocks will have an opt-out customer, so the meter reader will be able to skip many of those blocks.

CA IR-3 Attachment 1 also asserts that NS Power will dispatch its meter readers less efficiently for the opt-out customers. Rather than using the current system, which NS Power describes as "Meter Route-based; Meter Readers assigned a route(s)," it proposes to use "Service-Order dispatched work (G4 System)," as if the opt-out meter reads were service calls with unpredictable and varying locations. (Page 1) The same attachment also provides a map that is apparently meant to show some problem with serving opt-out customers who are not currently in the same meter-reading route, without explaining the nature of the perceived problem.

Finally, **CA IR-3 Attachment 1** notes that "MR2s today sometimes visit smaller communities only once a week" (CA IR-3 Attachment 1 Page 1), as if that were somehow a problem for reading meters once every 8 or 9 weeks. Again, NS Power seems to assume that opt-out meter reading would be no more routine that today's service calls.

In **CA IR-3a**, NS Power treats routine monthly or bimonthly meter-reading as equivalent to responding to special service orders, including the use of MR2 staff for reading rural meters, even though "Employees in the Meter Reader II and CFSR positions do not read meters on scheduled routes." (CA IR-3a)

VI. NS Power Modeling of Staffing and Non-Labour Costs

The NS Power model imposes several shortcomings related to staffing. The model assumes that:

- Meter-reading staff can only be hired full-time (Cells G22, G23)
- The urban meter readers will be basic Meter Readers, or MRs, as opposed to MR2 staff (Cell G24), and the rural readers will be MR2s.
- There must be one full-time MR2 Supervisor (Cells G27) and one full-time Meter Coordinator.
- While NS Power computed the depreciation, carrying charges and taxes based on the number of meter readers, the spreadsheet inputs these costs as fixed values.

We correct these arbitrary constraints as follows:

- We assume that meter-reading staff can be hired fractionally, in increments down to 0.2 FTEs, or one day per week. Fractional staff may work part time, or may fill other duties on other days. For example, one of the duties of MR2 staff is meter change-outs (Synapse IR-6(c)); NS Power expects to have about 10 MR2 to service the AMI meters.[7] Assuming non-integer FTEs is consistent with NSP's fractional use of labour for customer service calls (G35:G36), and its report that it currently has 2.5 meter coordinator FTEs.
- We assume that the meter readers are split between MRs and MR2s in the current ratio, with 71% MR.
- We set the MR2 Supervisor requirement at 0.05 times the number of other meter readers. According to Appendix B of the AMI application, NSP currently has 78 meter readers, and 0.038 supervisors per reader. Rounding up, the CA assumes that the supervisor and coordinator responsibilities are proportional to the current rates (but rounds up to the nearest 0.2 FTE).
- NS Power also assumes that it will need one full-time meter coordinator for the 62,434 meters in its analysis. Each of the 2.5 meter coordinators currently is responsible for 203,000 manually-read meters; the same ratio for the opt-out meters would require about 5% of an FTE. To be conservative, we assumed 0.2 FTE.
- We treat depreciation, carrying charges and taxes, which are related to the meter readers' cars and hand-held electronics, as proportional to the number of meter readers.

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[7] AMI Appendix B02. The count of 10 MR2s includes 5 of the CSFRs that NS Power says are essentially the same as MR2.

Figure 5 shows the results of these changes.

Figure 5: Incremental Cost of Opt-Out for Bimonthly Readings ($/Month), Corrected Model

	Times in Minutes			
Reading	Travel Between Opt-Out Meters			
	4	5	6	7
0.5	$2.36	$2.71	$3.29	$3.64
1	$2.53	$3.11	$3.46	$3.81
5	$4.27	$4.55	$4.97	$5.36

The revised labour requirements and scaling of the non-labour costs reduce the incremental costs by about $2/month compared to the values found in Figure 4.

Appendix 1: Model Descriptions

A. Top Down Model

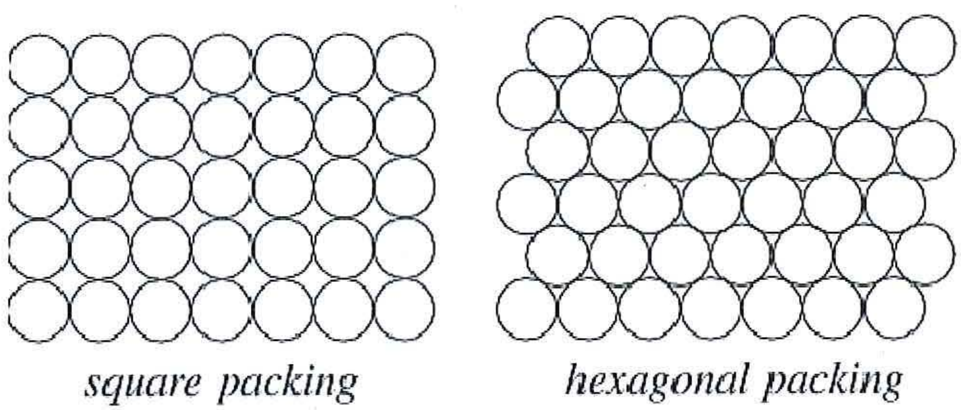
This model generates travel times in five steps.

1. Collect data on the population, number of households, and land area in each of Nova Scotia's 1,634 census tracts.[8] Remove the tracts where there are no dwellings (e.g. forest tracts).

2. Calculate the distance between non-AMI customers, assuming that they are evenly spaced within the census tract.

   a. Although census tracts are many shapes and sizes, for purposes of this analysis, we assume that the non-AMI customers are hexagonally packed circles within a rectangular census tract. A circle packing is an "arrangement of circles inside a given boundary such that no two overlap" and Figure A-1 illustrates two different circle packing techniques.[9]

Figure A-1: Example of circle packing (reproduced from Wolfram Mathworld)



Assume that each non-AMI customer is located at the center a circle, with the circles packing the number of customers in the census tract of a given radius. The distance to the nearest non-AMI neighbour is twice the radius of the circle. From packing theory, we know that closely packed circles have an efficiency rate of η=0.9069 (put differently, the area between circles is about 10% of the total area).

[8] Dissemination Area data from the 2016 Census: http://geosuite.statcan.gc.ca/geosuite/en/index

[9] http://mathworld.wolfram.com/CirclePacking.html

b. We can translate between the area of the census tract and area of the circles using the following identity, which states that the used area of the tract equals N circles of radius R.

$$\eta A_{Tract} = n\pi r^2$$

c. We rearrange this identity and find that the distance of each non-AMI customer from the nearest neighbour is:

$$D = 2 \times \sqrt{\frac{\eta A_{Tract}}{n\pi}}$$

d. The distance D between neighbours is "as the crow flies". We conservatively assume that the customers live on opposite corners of a square block. For example, if one customer lived south-east of another, then the meter reader would have to travel due east then due south to get from one to the other.

$$D_{traveled} = \frac{2}{\sqrt{2}} \times D_{crow} = \sim 1.414 \times D_{crow}$$

3. Calculate travel time between non-AMI neighbours within each census block, using specific values for walking speed and driving speed. (In Step 5, we run a sensitivity analysis on average travel time, using various walking and driving speeds.) Driving speeds range from 20 kph to 60 kph and walking speeds range from 3 kph to 5 kph. For distances under a threshold, the model assumes that the meter reader will walk between customers and drive if the distance is greater. For this analysis, we assume that the meter reader will walk if the distance between houses is less than ⅓ of a km.

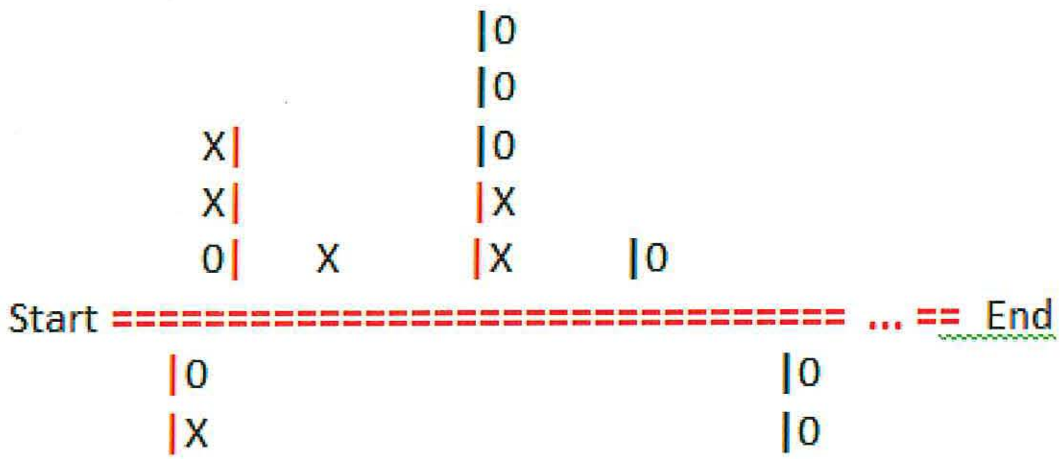
4. Calculate the dwelling-weighted average travel time across all 1,643 census tracts.

5. Run a sensitivity analysis exploring how average travel time changes based on different walking and driving speeds.

B. Bottom Up Model

The bottom up model simulates 250 simplified stretches of road with houses along a main road and on various spurs, then calculates the travel distance and travel time required to read meters along the road segment. Figure A-2 depicts a simplified version of the road where each "X" represents an opt-out customer and each "O" represents an AMI customer. The meter reader's route (in red) equals the full length of the main road plus out-and-back on spur roads to service the furthest opt-out customer.

Figure A-2: Sample Road Segment



The distance between houses on the main road is randomly sampled from a normal distribution whose mean and standard deviation were estimated using a survey of 20 randomly selected road segments in the province. The distance between houses on spurs is scaled from the main road distribution, using census data on housing counts and road mileage.

C. Housing Frequency Distributions

We randomly selected 15 stretches of main roads (mostly numbered routes), each 7 km in length, and counted the number of houses on the segment as well as the number of side roads. In total, we investigated 105 km of road with 95 spurs and 694 buildings. We assume that each building represents one customer, even though a single building may have multiple customers and some meters may serve more than one building. Details of this sampling are summarized in Figure A-3.

Figure A-3: Sample Distribution of Rural Buildings and Side Roads

Start Point (Lat/Long)	Raw Data			Km per		Units per km		Map Link
	Road #	Spurs	Buildings	Spur	Building	Spur	Building	
45.188, -63.297	2	5	88	0.71	12.57	1.40	0.08	https://goo.gl/maps/qvHoZf53JDr
45.186, -61.369	316	3	42	0.42	6	2.33	0.17	https://goo.gl/maps/KuZ5qcQQu8v
46.093, -60.497	223	4	48	0.57	6.86	1.75	0.15	https://goo.gl/maps/uPh1ixaF94x
44.710, -65.387	101	0	0	0	0			https://goo.gl/maps/61Gmut7mz5K2
44.827, -65.404	1	18	62	2.57	8.86	0.39	0.11	https://goo.gl/maps/bmNmKbwFwDk
45.658, -63.838	321	8	78	1.14	11.14	0.88	0.09	https://goo.gl/maps/dMSARkYoKmt
44.446, -64.807	325	4	11	0.57	1.57	1.75	0.64	https://goo.gl/maps/Mw2Y2ScqCt12
45.134, -63.540	None	4	5	0.57	0.71	1.75	1.40	https://goo.gl/maps/iSajqQqa2Mk
45.507, -64.692	209	1	0	0.14	0	7.00		https://goo.gl/maps/q49bbNUW5ry
45.146, -64.596	221	7	83	1	11.86	1.00	0.08	https://goo.gl/maps/dGq7ArgavVD2
44.403, -65.800	None	4	32	0.57	4.57	1.75	0.22	https://goo.gl/maps/gieBFbrYvmM2
45.812, -60.584	4	5	41	0.71	5.86	1.40	0.17	https://goo.gl/maps/GmUavSKJ3C62
44.474, -65.959	101	11	119	1.57	17	0.64	0.06	https://goo.gl/maps/8fFS4r3Ey3S2
45.853, -61.243	2	7	13	1	1.86	1.00	0.54	https://goo.gl/maps/A6WQnA5aua12
45.754, -61.465	19	14	72	2	10.29	0.50	0.10	https://goo.gl/maps/hH6cnhJFrCG2
Sum		95	694					
Average		6.33	46.27	0.90	6.61	1.68	0.29	
Standard dev		4.82	36.73	0.69	5.25	1.63	0.38	

From the sample roads, we approximate our simulated main road as a normal distribution with a mean of 0.29 km between buildings and a standard deviation of 0.38 km.[10] A spur or branch road splits off the main road at an average interval of 1.68 km, with a standard deviation of 1.63 km. We did not count the houses on the side roads, to avoid a raft of complications in defining the spur length. Instead, we estimated that distribution of houses on side roads as follows:

- We determined the implied number of rural customers on main roads as the length of non-divided numbered routes in the province (6,100 km), times the average number of customers per kilometer (6.6), or 40,318 customers.

- We estimated the rural customers would be on the side roads as the remainder of the 221,125 rural customers, or 180,807. Divided by the 10,400 km of non-numbered routes, that implies 17.4 buildings per km on the spurs, 2.6 times the density on the main roads.

- We estimated the number of spurs from the density of spurs in the sample (0.9/km of main road), times the length of main roads, or 5,519. That implies that the average spur has about 33 customers. Assuming that the 2% of opt-out customers are distributed randomly, a spur with 33 customers would have a 51% chance of having no opt-out customers (not requiring any travel time), a 35% chance of one opt-out customer, an 11% chance of two, 2% chance of three, and less than 4% probability of more. If the opt-out customers tend to cluster (due to the influence of neighbours, or the clustering of like-minded individuals), fewer branch rounds will have any opt-out customers.

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10 We take the absolute value of any random sample less than zero, which is an unlikely but possible occurrence, since the standard deviation is larger than the mean.

After generating a road network and populating it with meters according to the previously described distributions, we randomly select 2% of the customers to be opt-out customers. The length of the meter reading route is then calculated as the full length of the main roads plus twice the length of the furthest opt-out customer on each spur.

Because of the many variations on the spacing of opt-out customers on main roads, the distribution of opt-outs among and along the branch roads, and the distribution of branch roads, we employed a Monte Carlo simulation to generate 250 simulated road segments, each with a distinct pattern of side branches, customers and opt-out customers, and the associated travel time to serve the randomly generated opt-out meters. In each simulated road segment, house distances vary according to the random samples drawn from the different distributions. In various cases, houses may happen to be spread far apart or clustered, opt-out customers may be located at the end of long spurs or mostly near the main roads. In other cases, opt-out houses are much closer together and total travel distance to serve opt-out customers is relatively short. The average travel time across the 250 simulated road segments provides a good sense of the expected travel time.