# APPENDIX E: BACKGROUND ON AVOIDED DISTRIBUTION INVESTMENT

The Avoided Distribution Investment component was described as follows in Appendix D:

- When solar PV is installed near load, some of it will contribute to changes in EDC planning, such that some upgrade investments will be deferred[27] that otherwise would have been needed to provide additional capacity to meet peak growth; this is referred to as "active" deferral and applies to a subset of distribution area(s).
- In contrast, when solar PV is installed without integration into planning, there may be no deferral benefit in the short run, but over time it can nevertheless be assumed that, with experience, planning will take the solar into account, explicitly or implicitly, and this will lead to a "passive" deferral.
- Active and passive deferrals are estimated on the average and combined for the state.[28]

The Avoided Distribution Investment component represented a benefit to two of the four perspectives in this analysis: Non-Participating Ratepayers and Citizens at Large, as summarized in the following table:

| Policy | Participants | | Non-participating Ratepayers | Citizens of MA at Large |
|---|---|---|---|---|
| | Non-Owner Participants | Customer-generator (CG) | | |
| SREC, A, B | n/a | n/a | Costs deferred or avoided | Costs deferred or avoided |
| Notes: | Assume integration costs are internalized in charges to PV generators | | | |

The Avoided Distribution Investment methodology for this study had four main steps. The approach and assumptions are summarized below for each step.

**Step 1: Literature Review**

First, estimates of deferral benefits were taken from a literature review.

The following documents attempt to provide an overview of methodologies that have been and/or should be used to estimate the benefits and costs of solar PV for the T&D systems:

- A Regulator's Guidebook: Calculating the Benefits and Costs of Distributed Solar Generation, Interstate Renewable Energy Council, Inc., 2013, pages 26-30;
- Review Of Solar PV Benefit & Cost Studies, 2nd Edition, Rocky Mountain Institute, September 2013 (www.rmi.org/elab_emPower), pages 31-34.

[27] The deferral may last for many years in some cases, particularly where load growth is slow and the DER penetration is substantial, such that in present value terms the "deferral" is equivalent to "avoiding" most of the investment. See note 3.

[28] In addition to deferral of capacity investments, solar PV may have other grid support benefits, such as frequency and voltage regulation. There may also be grid integration costs that are not internalized through the interconnection process. These are complex subjects with changing technologies and rules, but for present purposes, these were not quantified and may be assumed to largely offset each other.

- Minnesota Value of Solar: Methodology, Minnesota Department of Commerce, Division of Energy Resources, by Clean Power Research, April 9, 2014, pages 31, 36, 41.

These methodologies distinguish between T&D capacity benefits and "grid support" impacts. For present purposes, while grid support benefits and costs may become increasingly important over time, we do not attempt to quantify them here, since there is little information available with which reliable estimates could be made for Massachusetts. We also assume that, to the extent solar interconnection and integration costs are incurred that are not internalized in the cash flows of solar owners, they are offset by grid support benefits.[29] Therefore, T&D capacity benefits are the only T&D benefits that are quantified in this report.

It is widely accepted that, under certain conditions, solar PV may contribute to economic savings by deferring the need to upgrade certain elements of the T&D system. The primary basis for the estimates of deferral benefits used in the present report is a set of economic values reported for case studies and planning studies that are publicly available. Specifically, the following seven sources provide a representative range of estimates.

1. "DG and Distribution Planning: An Economic Analysis for the Massachusetts DG Collaborative," Navigant Consulting, Attachment G to Report to DPU, Jan. 2006
2. "2014 System Reliability Procurement Report," The Narragansett Electric Company d/b/a National Grid, R.I.P.U.C. Docket No. 4453
3. Grid Solar Boothbay: Order Approving Stipulation, State of Maine Public Utilities Commission Docket No. 2011-138, April 30, 2012, Request for Approval of Non-Transmission Alternative (NTA) Pilot Projects for the Mid-Coast and Portland Areas
4. "The Value of Distributed Photovoltaics to Austin Energy and the City of Austin," Clean Power Research, L.L.C., March 17, 2006
5. "The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania," for Mid-Atlantic Solar Energy Industries Association & Pennsylvania Solar Energy Industries Association, by Perez, Norris & Hoff, Clean Power Research
6. "The Benefits and Costs of Solar Distributed Generation for Arizona Public Service," by Beach & McGuire, Crossborder Energy, May 8, 2013
7. "Evaluating the Benefits and Costs of Net Energy Metering in CA," prepared for The Vote Solar Initiative, Crossborder Energy, January 2013.

The following table compares the most relevant estimates from these seven sources, and shows their average value: $.016/kWh.

[29] This report has not addressed any possible differences between the Policy Paths in the ability to optimize these unquantified costs and benefits, such as by targeting feeders or other locations with relatively low interconnection costs for solar projects or with relatively high grid support benefits.

| Key Metrics from Literature Review | | | | A | B | C | D | E |
|---|---|---|---|---|---|---|---|---|
| | | | | T&D Capacity Value (2015 dollars) | | Deferral Benefit from PV with Specified DCP (2015 dollars) | | |
| | | | | Potential Deferral | | Active Deferral | | Statewide |
| | | | | $/kW or $/kVa | $/kW-year (not PV) | $/kW-year of PV | $/kWh of PV | $/kWh of PV |
| | | | | Blue= source value<br>Green= calculated value using assumptions as needed | | | | |
| 1 | **MA** | DG and Distribution Planning: An Economic Analysis for the Massachusetts DG Collaborative, Navigant Consulting, Attachment G to Report to DPU, Jan. 2006 | 2006 | $35 | $5 | $8 | $0.007 | **$0.002** |
| 2 | **RI** | 2014 System Reliability Procurement Report, The Narragansett Electric Company d/b/a National Grid, R.I.P.U.C. Docket No. 4453 | 2014 | | | $49 | $0.038 | **$0.012** |
| 3 | **ME** | Grid Solar Boothbay: Order Approving Stipulation, 2012 | 2012 | | | $281 | $0.220 | **$0.066** |
| 4 | **TX** | The Value of Distributed Photovoltaics to Austin Energy and the City of Austin, Clean Power Research, L.L.C., March 17, 2006 | 2006 | $1,516 | $64 | $31 | $0.025 | **$0.007** |
| 5 | **NJ & PA** | The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania, for Mid-Atlantic Solar Energy Industries Association & Pennsylvania Solar Energy Industries Association, by Perez, Norris & Hoff, Clean Power Research | 2012 | | | | | **$0.003** |
| 6 | **AZ** | The Benefits and Costs of Solar Distributed Generation for Arizona Public Service, by Beach & McGuire, Crossborder Energy, May 8, 2013 | 2013 | | | | | **$0.002** |
| 7 | **CA** | Evaluating the Benefits and Costs of Net Energy Metering in CA, prepared for The Vote Solar Initiative, Crossborder Energy, January 2013 | 2012 | | $55 (SCE)<br>$77 (SDG&E)<br>~$80 (PG&E) | | | **$0.022** |
| | | | | | | | **Average of values above** | **$0.016** |

One other study appeared too late to add into this average: "Value of Distributed Generation, Solar PV in Massachusetts," Acadia Center, April 2015. Its estimate of statewide deferral value for south-facing solar in Massachusetts -- $.018/kWh -- was only slightly above the average of the seven sources above, so it wouldn't have significantly changed the result.

Other sources provided relevant estimates of distribution investments or capital costs that are potentially deferrable (e.g., load or capacity upgrades), but stopped short of estimating deferral impacts.

As can be seen from the table, the literature includes a wide range of estimates. Also, different metrics are reported that are often not directly comparable. Where necessary (see green values in table), values have been converted to comparable units of dollars per solar kW and cents per solar kWh, using assumptions for solar capacity factor (for column D) and ELCC (solar match, for column E) that are consistent with the rest of the present project. Values have also been adjusted to 2015 dollars, using a 2.5% annual escalator.

**Step 2: Simplified Generic Worksheet of Distribution Deferral**

To confirm the reasonableness of the $.016/kWh average distribution deferral value from the literature, that value was compared against a simplified generic worksheet driven by a basic set of assumptions about distribution feeder load growth, upgrade cost, solar penetration and coincidence of solar output with feeder load. This worksheet illustrates the range of potential deferral benefits as these assumptions are varied, and provides additional confidence in the deferral value from the literature in step 1. The following table illustrates a scenario with a deferral from 2018 to 2037, which leads to a 56% savings in the present value of distribution investment required. The assumptions that lead to this scenario are listed below.

| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Upgrade cost incurred in year when needed | | | | | | | |
| | | Load as % of Capacity | | Year of Need for Upgrade | | Cost of Upgrade ($000) | Capital Cost & Timing of Upgrades ($000) | | Amortized Cost of Upgrades ($000), based on 30-year NPV | | |
| | | Existing | with DER | Existing | with DER | | Upgrade, No DER | Upgrade, with DER | Upgrades, No DER | Upgrades with DER | Annual Savings ($000) |
| 0 | 2015 | 98.0% | 83.0% | | | $250 | | | 100% | 44% | 56% |
| 1 | 2016 | 98.7% | 83.7% | 0 | 0 | 256 | | | $ | $ | $ |
| 2 | 2017 | 99.5% | 84.5% | 0 | 0 | 263 | | | $ | $ | $ |
| 3 | 2018 | 100.2% | 85.2% | 2018 | 0 | 269 | 269 | | $31 | $14 | $18 |
| 4 | 2019 | 101.0% | 86.0% | 0 | 0 | 276 | | | $31 | $14 | $18 |
| 5 | 2020 | 101.7% | 86.7% | 0 | 0 | 283 | | | $31 | $14 | $18 |
| 6 | 2021 | 102.5% | 87.5% | 0 | 0 | 290 | | | $31 | $14 | $18 |
| 7 | 2022 | 103.3% | 88.3% | 0 | 0 | 297 | | | $31 | $14 | $18 |
| 8 | 2023 | 104.0% | 89.0% | 0 | 0 | 305 | | | $31 | $14 | $18 |
| 9 | 2024 | 104.8% | 89.8% | 0 | 0 | 312 | | | $31 | $14 | $18 |
| 10 | 2025 | 105.6% | 90.6% | 0 | 0 | 320 | | | $31 | $14 | $18 |
| 11 | 2026 | 106.4% | 91.4% | 0 | 0 | 328 | | | $31 | $14 | $18 |
| 12 | 2027 | 107.2% | 92.2% | 0 | 0 | 336 | | | $31 | $14 | $18 |
| 13 | 2028 | 108.0% | 93.0% | 0 | 0 | 345 | | | $31 | $14 | $18 |
| 14 | 2029 | 108.8% | 93.8% | 0 | 0 | 353 | | | $31 | $14 | $18 |
| 15 | 2030 | 109.6% | 94.6% | 0 | 0 | 362 | | | $31 | $14 | $18 |
| 16 | 2031 | 110.4% | 95.4% | 0 | 0 | 371 | | | $31 | $14 | $18 |
| 17 | 2032 | 111.3% | 96.3% | 0 | 0 | 380 | | | $31 | $14 | $18 |
| 18 | 2033 | 112.1% | 97.1% | 0 | 0 | 390 | | | $31 | $14 | $18 |
| 19 | 2034 | 112.9% | 97.9% | 0 | 0 | 400 | | | $31 | $14 | $18 |
| 20 | 2035 | 113.8% | 98.8% | 0 | 0 | 410 | | | $31 | $14 | $18 |
| 21 | 2036 | 114.6% | 99.6% | 0 | 0 | 420 | | | $31 | $14 | $18 |
| 22 | 2037 | 115.5% | 100.5% | 0 | 2037 | 430 | | 430 | $31 | $14 | $18 |
| 23 | 2038 | 116.4% | 101.4% | 0 | 0 | 441 | | | $31 | $14 | $18 |
| 24 | 2039 | 117.2% | 102.2% | 0 | 0 | 452 | | | $31 | $14 | $18 |
| 25 | 2040 | 118.1% | 103.1% | 0 | 0 | 463 | | | $31 | $14 | $18 |
| 26 | 2041 | 119.0% | 104.0% | 0 | 0 | 475 | | | $31 | $14 | $18 |
| 27 | 2042 | 119.9% | 104.9% | 0 | 0 | 487 | | | $31 | $14 | $18 |
| 28 | 2043 | 120.8% | 105.8% | 0 | 0 | 499 | | | $31 | $14 | $18 |
| 29 | 2043 | 121.7% | 106.7% | 0 | 0 | 512 | | | $31 | $14 | $18 |
| 30 | 2044 | 122.6% | 107.6% | 0 | 0 | 524 | | | $31 | $14 | $18 |
| | | | | | **Sum** | | 269 | 430 | 878 | 388 | 490 |
| | | | | | **Net Present Value** | | **235** | **104** | **356** | **157** | **199** |
| | | | | | Levelized Values | | | | 27 | 0 | 15 |
| | | | | | **Upgrade and Savings Percentages** | | | | **100%** | **44%** | **56%** |

The assumptions which lead to this deferral from 2018 to 2037 are listed below, including a distribution feeder load growth rate of 0.75%/year, an upgrade cost of $250/kW, penetration of 15% for solar (or a combination of solar and other Distributed Energy Resources (DER), and coincidence of 33% between solar output and feeder load (equivalent to the ELCC, but at the distribution level; see Section 3.1 for a chart of this value over time). The following table also summarizes the results of this deferral scenario in present value terms:

- a 56% savings in the present value of distribution investment required, and
- a distribution deferral value of $.055/kWh for PV on this feeder (for "active deferral") from this simple model.[30]

Two additional calculations appear at the bottom of this table, which are described in Steps 3 and 4 below:

- a statewide (or "passive") distribution deferral value of $.016/kWh (which is nearly the same as the average from the literature in Step 1), after assuming (per Step 3 below) that 30% of the feeders statewide would have an opportunity for such an active deferral, and
- a net statewide distribution deferral value of $.008/kWh after assuming that deferral would be feasible on 50% of the feeders despite technical challenges discussed in Step 4 below.

**Illustrative Model of Upgrade Deferral by DER (4/27/15)**

Inputs: (input cell)

| | Inputs | |
|---|---|---|
| 1 | Feeder Capacity (MW) | 1.0 |
| 2 | Current Load % | 98% |
| 3 | Current Load (MW) | 1.0 |
| 4 | Peak Load Growth | 0.750% |
| 5 | New DER as % of Feeder Load | 15.0% |
| 6 | DER Reduction of Load (MW) | 0.147 |
| 7 | Upgrade Cost/kW * | $ 250.00 |
| 8 | Upgrade Capacity | 100% |
| 9 | Upgrade Capacity (MW) | 1.0 |
| 10 | Cost ($000, $/kW-yr) | $250 |
| 11 | Escalation of Upgrade Cost | 2.5% |
| 12 | Discount Rate/WACC | 7.0% |
| 13 | Carrying Chg/ Fixed Chg Rate (see sheet) | 13.3% |
| 14 | Solar DCP (Distrib Contrib as % of PV kW) | 33% |
| 15 | Solar MW (AC) | 0.445 |
| 16 | Solar MWh/yr | 567 |
| 17 | Deferral years | 19 |
| 18 | MWh in deferal years | 10,771 |

Results:

| Present Value Analysis: | Capital Costs: Upgrade, No DER | Capital Costs: Upgrade, with DER | Annual Costs: Upgrade, No DER | Annual Costs: Upgrade, with DER |
|---|---|---|---|---|
| Upgrade Cost ($000) | $ 220 | $ 97 | $ 333 | $ 147 |
| Savings ($000) | | $ 123 | | $ 186 |
| Savings (% reduction) | | 56% | | **56%** |
| Savings $/kW of DER | | $ 834 | | $ 1,262 |
| Savings $/kW of Solar | | $ 275 | | **$ 1,043** |

| | This Run | Weighted* |
|---|---|---|
| Cumulative Savings $/kWh of Solar | $ 0.0617 | $ 0.0548 |

* *Weighted by load growth and DER penetration*

| | Active | % of load on feeders with growth | Statewide |
|---|---|---|---|
| Distribution Deferral for PV across territory from model ($/kWh) | $ 0.0548 | 30% | $ 0.0164 |
| Average of 5 values from the literature ($/kWh) | $ 0.0542 | 30% | $ 0.0163 |
| Weighted/selected results | $ 0.0542 | | $ 0.0163 |
| Adjustment for technical issues | | | 50% |
| Assumed Distribution Deferral for PV ($/kWh) | | | $ 0.0081 |

[30] The amortized Annual Savings in column (10) are divided by the cumulative solar kW installed each year to defer the investment, and then the resulting $/kW annual savings are divided by solar output each year and levelized for this active deferral value of $.055/kWh.

**Step 3: Opportunities to Defer Distribution Investments**

We make an assumption for the percentage of the state's distribution system to which estimates of "active deferral" are applicable; this is the portion of the system that is growing and so will require new capacity or otherwise provides opportunities to defer distribution investments.[31] We have used 30 percent as a placeholder assumption for this factor. This was applied to estimates from four of the literature sources and to the results from the worksheet in Step 2 to get a statewide distribution deferral value of $.016/kWh.[32]

**Step 4: Technical Factors to Achieve Deferral**

There are a number of factors that may be required in order for distribution planners to sufficiently rely upon solar DG to actually achieve a deferral of upgrade investments. Some of these factors may affect the physical availability of PV to reduce load under challenging conditions, such as following power quality disturbances and grid outages; planning lead time is also a factor.

These factors include:

- IEEE 1547 standards requires DG to trip for low voltage and other disturbances, and low-voltage ride-through may be incompatible with anti-islanding protection;
- Planners can't count on PV to be on-line instantly as power is restored after outage; and,
- Physical assurance may be needed to keep load off the distribution system if the solar goes down.

These issues are important and should be addressed through further R&D, pilot testing and policy development. This will lead to better information to estimate their impact on the benefits and costs of solar for the T&D system. In the meantime, we simply apply a factor for the percentage of PV that can be counted upon for distribution deferral through the use of physical assurance, storage, smart inverters with ride-through, linked demand response and/or other means. We have used 50 percent as a placeholder assumption for this factor, resulting in a net statewide distribution deferral value of $.008/kWh.

**Results**

[31] For portions of the distribution system on which there is literally no load growth, there is essentially no deferral opportunity for DER. However, the deferral benefit is at its highest with load growth around ½ of 1 percent/year, other things being equal, since DER (at an assumed 10% penetration) can not only defer the upgrade but avoid it for an entire 30-year period.

[32] The average values used in this report will not be representative of any particular location.

The result for steps 1 through 3 for this illustration was $.016 average statewide value of Avoided Distribution Investment per kWh of solar PV. After applying the 50% factor from Step 4, the net value = $.008/kWh. The modeling for this study replaced the static assumption for peak coincidence described above with the with the solar penetration-dependent value for each year, calculated as discussed in Section 3.1.