**Caiazza Personal Comment on Draft Scoping Plan Residential Heating Electrification Estimates**

**Summary**
In my opinion, home electrification is a primary concern for New Yorkers given the importance of affordability and the impact to every household. Accordingly, I spent a lot of time trying to replicate the costs to retrofit existing furnaces with heat pumps as documented in these comments. I found that the existing documentation is too incomplete to be able to reproduce the cost projections.

These comments found that a primary driver of home heating electrification is the building shell cost. Given its importance all the assumptions used to generate the numbers must be available but there is insufficient documentation. The Draft Scoping Plan claims only 26% of residences need deep shell upgrades. I estimate that more than half actually will need to have deep shell upgrades using a more refined climatology. I estimate that the entire building sector component cost is $230 billion relative to the reference case in the Draft Scoping Plan. I calculated that just the residential retrofit heat electrification costs range between $259 billion and $370 billion using one methodology and between $295 billion and $370 billion based primarily on the number of residences that need deep building shell upgrades.

I conclude that all of the material described in the section “What needs to be provided” must be publicly available to fulfill the obligations of the Climate Act and ensure that cost information necessary to determine whether PSC mandates are met. The Integration Analysis documentation has to be supplanted and the Draft Scoping Plan needs to be revised to specifically address these obligations.

**3.3 Sectoral Results -Buildings: Appendix G, Integration Analysis Technical Supplement Section I**
The primary reference for technical information related to the building sector is Appendix G, Section I. In this section I reproduce that text and include my indented and italicized comments.

Direct emissions in the buildings sector are dominated by emissions from space and water heaters (note that indirect emissions associated with electricity generated to power electric appliances are captured under electricity generation). Although population and households are expected to grow in New York, all scenarios see a significant decline in building sector emissions through energy efficiency, rapid electrification, and improved building shells[21].

> *The relative importance of these strategies is not included.*

To achieve the reductions in energy use and emissions shown in Figure 22, rapid adoption of new technologies will be required. In all scenarios, electric heat pump space heating technology systems become the majority of new purchases by the late 2020s and no fossil-emitting appliances are sold after 2035. As a result, the electricity share of final energy demand increases from 30% in 2020 to 89%-92% by 2050 across Scenarios 2-4. Base year equipment characteristics and device populations are available in Annex 1, while annual sales and stocks of devices are reported in Figure 23 and Figure 24 below as well as in Annex 2 along with annual sectoral energy demand and GHG emissions.

[21] Adoption of energy efficiency measures, efficient building shell measures, and heat pump systems affects all existing fuels used for primary heating in buildings (e.g., natural gas, petroleum fuels, and wood)

*Building shell assumptions are not included. For example, stocks of devices for each of the areas that determine what type of building shell are not included.*

In all scenarios electric heat pump space heating technologies are predominantly cold climate air source heat pumps (ASHPs) with electric backup and a significant role for ground source heat pumps (GSHPs); ASHPs are significantly more efficient than electric resistance heaters during most heating load conditions but lose efficiency during the coldest hours of the year and require some backup heat source. ASHPs with electric backup use electric resistance as the backup heat source, resulting in increased electric system peak impacts (but generally lower than purely resistance heaters alone), whereas ASHPs with fuel backup use combustion or thermal heat sources to provide backup heat while ground source heat pumps operate with little to no performance degradation in cold conditions (Table 3). To represent a lower range of electric peak system impacts, Scenario 2 includes a small share of ASHPs with fuel backup. Scenarios 3 and 4 also include a role for early retirements of least efficient and most polluting space heaters. We also include a ground source / district heating loop sensitivity, which is described in more detail in Chapter 3.5.

*It is good that this section acknowledges that backup heat sources are needed during the coldest hours of the year but it is disingenuous to suggest that they will be needed only for hours. The fact is during the coldest periods last for days not hours. "Scenario 2 includes a small share of ASHPs with fuel backup" but the document does not describe what types of fuel backup are projected. Nor is there any consideration that fuel supply for a limited number of users might be problematic.*

Building shell improvements (such as improved insulation, window treatments, or deep home retrofits) are modeled as reducing service demand for HVAC devices. Improvements to buildings incur costs but improve home and office comfort in addition to reducing energy bills. Two bundles of building shell improvements have been included: a basic shell upgrade and a deep shell upgrade. Basic and deep shell upgrades include a variety of measures focused on reducing energy use and increasing occupant comfort; these measures include, for example, varying levels of roof and wall insulation improvements, window treatments such as double or triple paned windows and infiltration improvements. Space heating demands are reduced by 27-44% with the basic shell package and 57-90% with the deep shell package, depending on building type. Air conditioning demands are reduced 14-27% with the basic shell package and 9-57% with the deep shell package. The total impact of building shell improvements on total HVAC service demand in buildings is a function of the market penetration of each package and distribution of building types. Building shell improvements include both retrofits and new construction, although all new construction in residential and commercial is assumed to be code-compliant and therefore has lower HVAC service demands relative to the existing building stock.[22]

*This paragraph lists the building shell improvement characteristics but does not describe the rationale for applying basic vs. deep shell packages. There is an enormous difference between the costs of the two types of building shells and there is insufficient documentation to determine how the Integration Analysis apportioned the technology across buildings in the state. It is not clear if these building shell improvements also include air exchangers. Sealing a home without adequate ventilation has led to problems elsewhere.*

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[22] E3 calculated the stock rollover of building shells with a 20-year lifetime to reflect improvements in new construction and opportunities for home retrofits.

**Calculation of Residential Heating Conversion to Electrified Heating**

I tried to reproduce the cost estimates in the Draft Scoping Plan by estimating costs independently. In brief the calculation of residential heating sector costs is simply the number of residences multiplied by the costs to electrify heating appliances and building shell upgrades. The Scoping Plan Analysis Residential Heating spreadsheet contains my calculations for converting the New York residential sector. In this analysis, I only consider the costs to retrofit technology at the end of the useful life of non-electric appliances.

Table 1 describes the tabs included. The spreadsheet has seven tabs that contain my calculations. The remaining tabs are from the Appendix G Integration Analysis Technical Supplement. Five tables copied from the "IA-Tech-Supplement-Annex I-Inputs-Assumptions" spreadsheet and ten tables copied from the "IA-Tech-Supplement-Annex 2 Key Drivers" spreadsheet.

**Evaluation of Residence Types**

In the 2021-12-29-IA-Tech-Supplement-Annex I-Inputs-Assumptions spreadsheet the Bldg_Housing Unit Summary tab has seven tables that list different housing types. There are three tables with four housing types: Large Single Family, Small Single and Multi-Family, and High Rise Multi-Family, and Mobile Home. The housing types used in the other tabs of the spreadsheet list three housing unit types: single family, small multi-family, and large multi-family. There is no documentation explaining how these housing types map each other. As a result, it is impossible to reproduce the Draft Scoping Plan cost estimates. In the Scoping Plan Analysis Residential Heating spreadsheet, in tab "Shells by Region" I list my map for the housing types.

**Table 1: Scoping Plan Analysis Residential Heating Spreadsheet**

| Spreadsheet Source | Tab Name | Contents |
|---|---|---|
| Scoping Plan Analysis Residential Heating | Cover | Summary of spreadsheet tabs |
| Scoping Plan Analysis Residential Heating | # Homes Calculation | Number of residences by type of technology |
| Scoping Plan Analysis Residential Heating | Simple Estimate | Number of residences multiplied by cost of technology |
| Scoping Plan Analysis Residential Heating | Differential Cost | Differential cost of technology multiplied by number of residences |
| Scoping Plan Analysis Residential Heating | Shells by Region | Building shell by region (Tables 3-5) in comments |
| Scoping Plan Analysis Residential Heating | Building Shells | Consolidated Building Shell Stocks from Key Drivers Building Shells tables |
| IA-Tech-Supplement-Annex 2 Key Drivers | AP Shell | Building shell stocks and sales, S1_Building Shell |
| IA-Tech-Supplement-Annex 2 Key Drivers | S2_Building Shell | Building shell stocks and sales, S2_Building Shell |
| IA-Tech-Supplement-Annex 2 Key Drivers | S3_Building Shell | Building shell stocks and sales, S3_Building Shell |
| IA-Tech-Supplement-Annex 2 Key Drivers | S4_Building Shell | Building shell stocks and sales, S4_Building Shell |
| IA-Tech-Supplement-Annex I-Inputs-Assumptions | Bldg_Housing Unit Summary | 2018 estimated distribution of various housing unit statistics (type of unit by region) |
| IA-Tech-Supplement-Annex I-Inputs-Assumptions | Building Sector Coverage | Summary of building subsectors, stock, energy demand |
| IA-Tech-Supplement-Annex I-Inputs-Assumptions | Bldg_Res Stock | Initial year stock by subsector, device lifetimes, and 2020 sales efficiency |
| IA-Tech-Supplement-Annex I-Inputs-Assumptions | Bldg_Res Efficiency | Summary of forecast device efficiencies for residential technologies |
| IA-Tech-Supplement-Annex I-Inputs-Assumptions | Bldg_Res Device Cost | Summary of device costs for residential devices |
| IA-Tech-Supplement-Annex 2 Key Drivers | Reference_Space Heating-Res | Residential space heating stocks and sales, Reference case |
| IA-Tech-Supplement-Annex 2 Key Drivers | Reference_Building Shell | Building shell stocks and sales, Reference case |
| IA-Tech-Supplement-Annex 2 Key Drivers | S1_Space Heating-Res | Residential space heating stocks and sales, S1 |
| IA-Tech-Supplement-Annex 2 Key Drivers | S2_Space Heating-Res | Residential space heating stocks and sales, S2 |
| IA-Tech-Supplement-Annex 2 Key Drivers | S3_Space Heating-Res | Residential space heating stocks and sales, S3 |
| IA-Tech-Supplement-Annex 2 Key Drivers | S4_Space Heating-Res | Residential space heating stocks and sales, S4 |

**Evaluation of Residential Building Shells**

Appendix J: Integration Analysis Technical Supplement Section I (page 34) describes the energy efficiency and building shell improvements that are necessary to effectively electrify residential home heating in New York State:

> Building shell improvements (such as improved insulation, window treatments, or deep home retrofits) are modeled as reducing service demand for HVAC devices. Improvements to buildings incur costs but improve home and office comfort in addition to reducing energy bills. Two bundles of building shell improvements have been included: a basic shell upgrade and a deep shell upgrade. Basic and deep shell upgrades include a variety of measures focused on reducing energy use and increasing occupant comfort; these measures include, for example, varying levels of roof and wall insulation improvements, window treatments such as double or triple paned windows and infiltration improvements. Space heating demands are reduced by 27-44% with the basic shell package and 57-90% with the deep shell package, depending on building type. Air conditioning demands are reduced 14-27% with the basic shell package and 9-57% with the deep shell package. The total impact of building shell improvements on total HVAC service demand in buildings is a function of the market penetration of each package and distribution of building types. Building shell improvements include both retrofits and new construction, although all new construction in residential and commercial is assumed to be code-compliant and therefore has lower HVAC service demands relative to the existing building stock.[22]

A primary goal in my comment analysis is to determine how many buildings are converted to basic and deep shells. In the IA-Tech-Supplement-Annex-2-Key-Drivers-Outputs spreadsheet there are five tabs with Building Shells as part of the name for the reference case and four scenarios. In the attached Scoping Plan Analysis Building spreadsheet tab "Building Shells" the Building Shell Stocks (million buildings) table within each of the five data tabs is consolidated. Table 2 summarizes the building shell stocks as a percentage of the total for the reference case and four mitigation scenarios for 2019, 2025, 2030, 2040, and 2050. Note that the percentage of reference shell, basic shell and deep shell homes in Scenarios 2-4 are all the same.

[22] E3 calculated the stock rollover of building shells with a 20-year lifetime to reflect improvements in new construction and opportunities for home retrofits.

**Table 2: Building Shell Stocks (% of total)**

| Basic Shell | | | | | |
|---|---|---|---|---|---|
| **Scenario** | **2019** | **2025** | **2030** | **2040** | **2050** |
| **Reference** | 0% | 2% | 4% | 8% | 10% |
| **Scenario 1** | 0% | 3% | 10% | 35% | 56% |
| **Scenario 2** | 0% | 6% | 18% | 45% | 66% |
| **Scenario 3** | 0% | 6% | 18% | 45% | 66% |
| **Scenario 4** | 0% | 6% | 18% | 45% | 66% |

| Deep Shell | | | | | |
|---|---|---|---|---|---|
| **Scenario** | **2019** | **2025** | **2030** | **2040** | **2050** |
| **Reference** | 0% | 2% | 3% | 4% | 5% |
| **Scenario 1** | 0% | 2% | 3% | 8% | 12% |
| **Scenario 2** | 0% | 3% | 7% | 18% | 26% |
| **Scenario 3** | 0% | 3% | 7% | 18% | 26% |
| **Scenario 4** | 0% | 3% | 7% | 18% | 26% |

| Reference Shell | | | | | |
|---|---|---|---|---|---|
| **Scenario** | **2019** | **2025** | **2030** | **2040** | **2050** |
| **Reference** | 100% | 97% | 94% | 88% | 85% |
| **Scenario 1** | 100% | 95% | 87% | 57% | 31% |
| **Scenario 2** | 100% | 92% | 75% | 38% | 8% |
| **Scenario 3** | 100% | 92% | 75% | 38% | 8% |
| **Scenario 4** | 100% | 92% | 75% | 38% | 8% |

In order to estimate building shell upgrade costs, the first item needed is how the building shells are applied to different housing types. In the Scoping Plan Analysis Residential Heating spreadsheet, tab "Shells by Region" I list my conversion map for the housing types.

The second item needed to evaluate building shell projections is an estimate of how many buildings will be converted to upgraded building shells. The Bldg_Housing Unit Summary tab includes a table that lists Total Housing Units by CLCPA PW Zones which I believe refers to Pathway zones. Table 3 compares basic, deep, and reference shell projections for the scoping plan scenario and five test cases with differing percentages of basic shell upgrades. Inputting the basic shell percentage by region, the shell percentages for the state as a whole are calculated. It is assumed that the reference case percentage is constant and equal to the percentage of mobile homes in these test cases. I tried to cover a range of building shell upgrades as a function of five different regions of the state that have differing heat needs based on their climatic histories. For this table I only broke it down by three climatic zones: Upstate, Lower Hudson Valley, and New York City and Long Island. In Test 2 I assumed 25% of the homes Upstate, 85% in the Lower Hudson Valley, and 90% of the homes on Long Island and in New York City need basic shells for electric heat. Applying those percentages to the number of homes in the five CLCPA PW zones provides an estimate of basic, deep and reference shell that is close to the Scoping Plan percentages.

**Table 3: Comparison of Basic Shell Scenarios by CLCPA PW Zone**

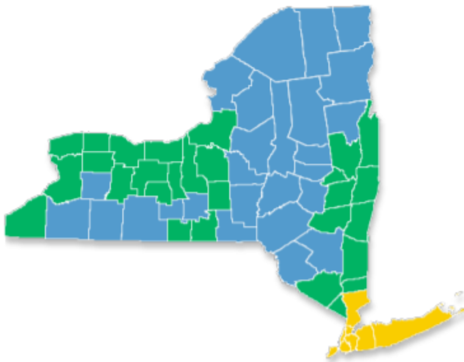
| | Scoping Plan | Test 1 Basic % | Test 2 Basic % | Test 3 Basic % | Test 4 Basic % | Test 5 Basic % |
|---|---|---|---|---|---|---|
| **Upstate NY A-E** | | 30% | 25% | 20% | 15% | 10% |
| **Upstate NY F** | | 30% | 25% | 20% | 15% | 10% |
| **Downstate NY - Lower Hudson Valley** | | 90% | 85% | 75% | 65% | 55% |
| **Downstate NY - Long Island** | | 95% | 90% | 85% | 80% | 75% |
| **Downstate NY - New York City** | | 95% | 90% | 85% | 80% | 75% |
| **Basic Shell** | 66% | 71% | 66% | 61% | 55% | 50% |
| **Deep Shell** | 26% | 27% | 31% | 37% | 42% | 48% |
| **Reference Shell** | 8% | 2% | 2% | 2% | 2% | 2% |

The Draft Scoping Plan admits that a backup heat source will be required because of the New York climate. In this context my concern is that homeowners with inadequate shell upgrades will need to rely on backup electric resistance heating so much that the energy load for the worst-case peak load period will be underestimated. In my opinion the percentage of homes in the Lower Hudson Valley, Long Island, and New York City with basic shell upgrades in the Plan instead of deep shell upgrades is far too high. That suggests that the peak load estimates will be wrong as well as the cost estimates that are strongly affected by building shell upgrade costs.

The Bldg_Housing Unit Summary tab includes another table that lists Total Housing Units by Pathways Housing Unit Type that includes NYSERDA climate zone categories for each county. As far as I can tell, these climate zones use the International Energy Conservation Code. As shown below there are only three climate zones. Using the same methodology as before I calculated the building shell upgrades for different test levels and conclude that the Draft Scoping Plan under-estimates the number of deep shell upgrades that will be needed (Table 4).

This breakdown of the building shell distribution by climate zone also indicates that the percentage of basic shell upgrades in climate zones 5 and 6 would have to be unrealistically high. In order to keep a residence warm using an air source heat pump I believe deep shell upgrades need to be the rule rather than the exception. The Integration Analysis estimates are too low.

**Figure 1: New York State Climate Zones**



| | | | |
|---|---|---|---|
| **Climate Zone 4** | | | |
| Bronx | Nassau | Queens | Suffolk |
| Kings | New York | Richmond | Westchester |
| **Climate Zone 5** | | | |
| Albany | Erie | Ontario | Saratoga |
| Cayuga | Genesee | Orange | Schenectady |
| Chautauqua | Greene | Orleans | Seneca |
| Chemung | Livingston | Oswego | Tioga |
| Columbia | Monroe | Putnam | Washington |
| Cortland | Niagara | Rensselaer | Wayne |
| Dutchess | Onondaga | Rockland | Yates |
| **Climate Zone 6** | | | |
| Allegany | Franklin | Montgomery | Sullivan |
| Broome | Fulton | Oneida | Tompkins |
| Cattaraugus | Hamilton | Otsego | Ulster |
| Chenango | Herkimer | Schoharie | Warren |
| Clinton | Jefferson | Schuyler | Wyoming |
| Delaware | Lewis | St. Lawrence | |
| Essex | Madison | Steuben | |

I have a B.S. and M.S. in meteorology, have over 45 years of experience, and was certified as a consulting meteorologist. In my opinion, there is a better, more detailed climate zone map for building shell upgrade estimates that I used for another estimate of building shell requirements with my recommended climate zone classification. The United States Department of Agriculture plant hardiness map has nine zones for New York (Figure 2). It uses the average annual extreme minimum temperature for its classification that believe that is a good indicator for building shells when using heat pumps. Note that the average minimum is above zero for only two of the nine zones, corresponding roughly to Integration Analysis climate zone 3. I categorized this as zone 4. For the most part it appears that New York Climate zone 5 should correspond to NYSDA zones 6a and 6b. As a result, I limited zone 5 to the lower Hudson Valley and counties along the Great Lakes. I categorized all the counties in the Mid- and Upper Hudson Valley as zone 6 as well the counties along the Pennsylvania border except Chautauqua County along Lake Erie. If the average annual extreme minimum temperature is less than equal to -10°F (USFDA zones 3b, 4a, 4b, 6a, and 6b) then I believe another climate zone should be included. I categorized Allegheny and Cattaraugus counties as well as counties in the Adirondacks as climate zone 7 to meet this criterion. This is documented in the Caiazza Climate zones table in tab “Shells by region”.

Using this more refined climate zone categorization and the same methodology there is an even bigger discrepancy between a more realistic estimate of deep shell upgrades needed and the Draft Scoping Plan (Table 5). The Draft Scoping Plan claims only 26% of residences need deep shell upgrades. I estimate that more than half actually will need to have deep shell upgrades using this methodology. This is double what the Integration Analysis estimates and has a big effect on costs.

**Table 4: Comparison of Basic Shell Scenarios by NYSERDA Climatic Zones**

| | Scoping Plan | Test 1 Basic % | Test 2 Basic % | Test 3 Basic % | Test 4 Basic % | Test 5 Basic % |
|---|---|---|---|---|---|---|
| NYSERDA Climate Zone 4 | | 70% | 75% | 80% | 85% | 90% |
| NYSERDA Climate Zone 5 | | 15% | 25% | 35% | 45% | 55% |
| NYSERDA Climate Zone 6 | | 5% | 10% | 15% | 20% | 25% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Basic Shell | 66% | 31% | 38% | 44% | 50% | 56% |
| Deep Shell | 26% | 66% | 60% | 54% | 48% | 41% |
| Reference Shell | 8% | 2% | 2% | 2% | 2% | 2% |

**Figure 2: USDA Plant Hardiness Map**

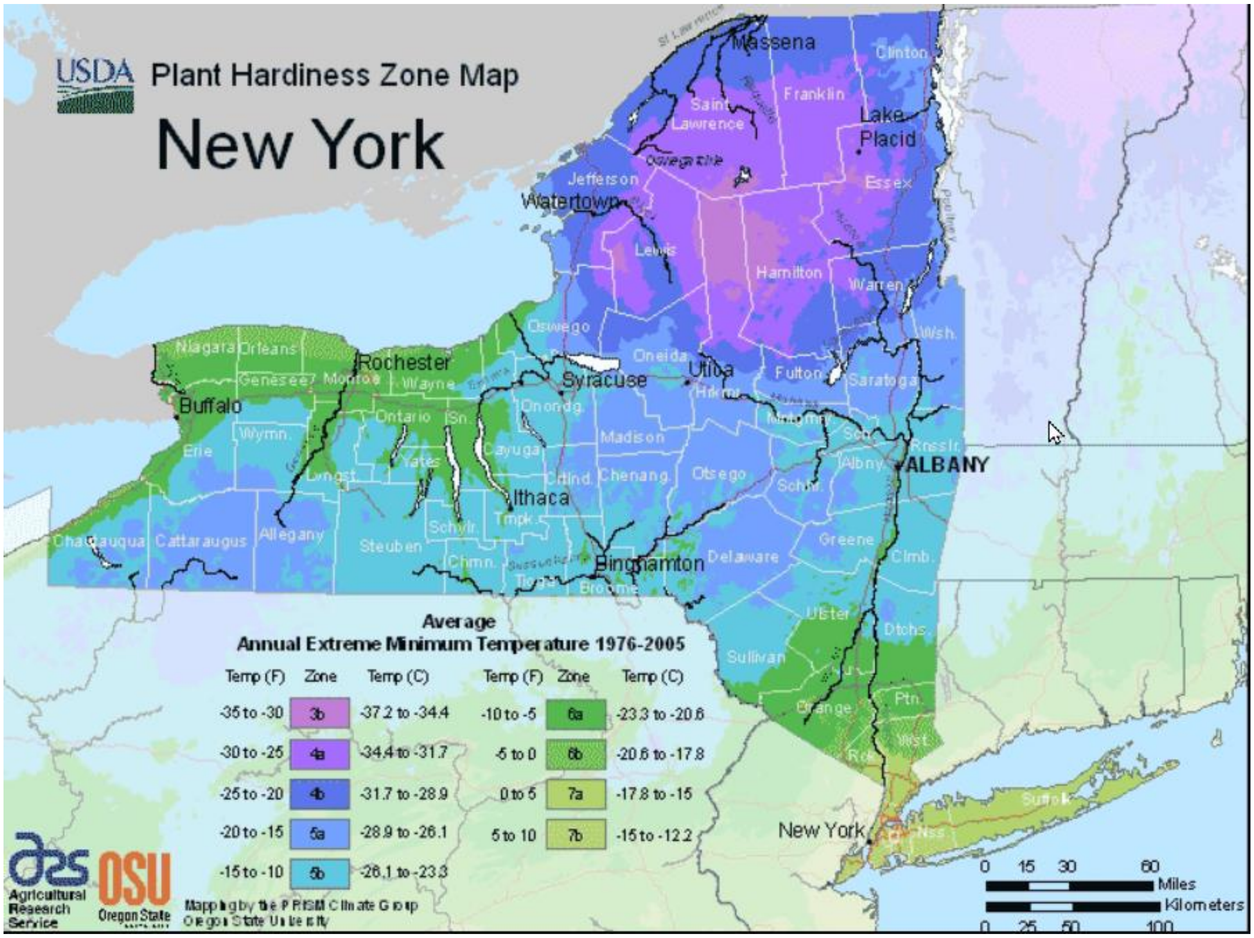



**Table 5: Comparison of Basic Shell Scenarios by USDA Plant Hardiness Climatic Zones**

| | Scoping Plan | Test 1 Basic % | Test 2 Basic % | Test 3 Basic % | Test 4 Basic % | Test 5 Basic % |
|---|---|---|---|---|---|---|
| USDA Plant Climate Zone 4 | | 70% | 75% | 80% | 85% | 90% |
| USDA Plant Climate Zone 5 | | 15% | 25% | 35% | 45% | 55% |
| USDA Plant Climate Zone 6 | | 5% | 10% | 15% | 20% | 25% |
| USDA Plant Climate Zone 7 | | 0% | 5% | 10% | 15% | 20% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Basic Shell | 66% | 29% | 35% | 41% | 47% | 52% |
| Deep Shell | 26% | 68% | 63% | 57% | 51% | 45% |
| Reference Shell | 8% | 2% | 2% | 2% | 2% | 2% |

**Evaluation of Residential Heating Device Costs**

I tried to independently reproduce the cost estimates in the Draft Scoping Plan. This section describes my analysis of heating appliances costs. 2021-12-29-IA-Tech-Supplement-Annex I-Inputs-Assumptions spreadsheet, tab "Bldg Device Cost" lists the costs for building shell upgrades and space heating appliances. In my analysis I only considered the cost for retrofits so the heating appliance cost is the difference between the cost to replace an existing appliance subtracted from the cost of an air source or ground source heat pump.

In the attached Scoping Plan Analysis Residential Heating spreadsheet, tab "Bldg Res Stock" lists the existing number of building shells and appliances for single family, small multi-family and large multi-family residences. The Integration Analysis applies the annual appliance cost by a number of residences to get the cost. There are tabs with tables that list the number of sales of different types of heating appliances for all the scenarios. However, it is not clear exactly how the final cost estimates are determined.

Consider for example, the "S2_Space Heating-Res" tab where I have annotated the original version from the IA-Tech-Supplement-Annex 2 Key Drivers spreadsheet. There are three sets of tables: all building types, single family, and multi-family. Each set contains four tables that list annual data from 2020 to 2050. The Residential Space Heating Sales (thousand devices) lists eight device types including "heat pump". The Residential Space Heating Sales Share (% total sales) and Residential Space Heating Stocks (million devices tables list the same eight device types but also break down heat pumps into five sub-categories: ductless air source heat pump, ground source heat pump, hybrid gas electric heat pump, hybrid oil electric heat pump, and hybrid heat pump. However. this distinction is only made in the all building types set of tables. The last table, HP Summary Metrics, has four rows: sales share, stock share HP, total HP stock and total diesel stock. The last category is only in this set of tables too. Frustratingly, the distribution between air and ground source heat pumps is not listed for each building type.

There are some issues with these tables. It is not clear to me why there is a reference to ductless air source heat pumps. My interpretation of the text was that the "plan" was to retrofit heat pump furnaces using existing ducts where furnaces are presently used. Furthermore, there is no device cost listed for ductless air source heat pumps. There is no apparent reason for this category to be included.

There is an issue with the heat pump estimates in 2050 for this spreadsheet. In row 80, the Strategic Use of Low-Carbon Fuels scenario, for Device Category Heat Pump the spreadsheet claims that there will be 7,805,950 devices in 2050. However, the sum of the five types of heat pumps in rows 84 through 88 is 8,522,651. Why is there a difference?

Finally, the 2050 total for total heating stocks is 8,466,788 devices for Scenario 2 (row 82). However, there are differences for the other scenarios and reference case. The reference case has 8,399,847 devices, Scenario 1 has the same rounded number of devices, 8,466,788, Scenario 3 8,465,0924 devices, and Scenario 4 8,465,092 devices. It is not clear why there should be variations in the total number of residential heating devices due to the scenarios.

I estimated costs in two ways. The tab “Simple Estimate” converted by year to get an annual conversion cost which then are summed up to get a total cost. However, the “Bldg Device Cost” tab does not vary the appliance costs by year so I just multiplied the appliance cost by the total number of residences in each category to estimate the total costs.

In the tab “Simple Estimate” I used the 2018 total number of residences and appliance costs to estimate total costs to electrify existing residences. For building shells, I distributed the number of existing residences by the percentage of basic, deep and reference shells from the Integration Analysis. I estimate that upgrading building shells alone would cost $158.3 billion. My best estimate of the building shell distribution using the plant hardiness climate zones (38% basic, 54% deep, and 8% reference) gives a building shell estimate of $233.7 billion. That is $75.5 billion or 48% more than the simple estimate using the building shell distribution from my estimate of the Integration Analysis distribution.

The tab also calculates the cost for the heating appliances. My estimates are only for residential heating retrofits so the projection equals the cost of heat pumps less the cost of replacement heating appliances. The calculation combines the residential stock and the device costs and multiplies the values to estimate the cost of replacement heating appliances.

In order to estimate the heat pump costs it is necessary to know how many will be air source versus ground source. I was unable to determine that distribution in the Integration Analysis spreadsheets or the Draft Scoping Plan. Appendix G states: “In all scenarios electric heat pump space heating technologies are predominantly cold climate air source heat pumps (ASHPs) with electric backup and a significant role for ground source heat pumps (GSHPs)”. The Ground Source / District Loop Heat Pump Deployment Sensitivity Analysis states that “The sensitivity includes an assumption of increasing ground source and district heat pump market penetration over time, with 40% of heat pump sales being assumed to be ground source/district heat pumps by 2035, 60% by 2040, and 80% by 2045.” However, the obvious question what was the ground source heat pump penetration in the mitigation scenarios is not answered as far as I can tell. In the absence of any documentation, I assumed 70% would be air source and 30% would be ground source.

The “simple estimate” approach projects that the one-time cost to replace all existing heating appliances would be $37.7 billion and that the retrofit cost for 70% air source heat pumps and 30% ground source heat pumps would be $174.1 billion. This makes the retrofit cost $136.4 billion for the appliances. Building shell upgrades necessary to make heat pumps viable in New York’s climate adds $158.3 billion and that adds up to a total of $294.6 billion.

I calculated residential home heating electrification retrofit costs in a different way in the “Differential Cost” tab in the attached spreadsheet. The advantage of this approach is that individual costs per type of existing heating source can be calculated. The analysis uses device costs for three categories of residential households: large multi-family, small multi-family and single family for the three types of building shell upgrades and for air source heat pumps, electric resistance backup heat, and ground source heat pumps from the Integration Analysis spreadsheet. Those values are listed at the top of

Table 1 in the Component Costs and Total Electrification Estimate section. For each category of building type different heating appliances are listed along with their estimated cost. The main body of the table looks at the resulting combination of costs per household, building shell type, and type of existing heating system. I assumed in the table that ground source heat pumps would not require backup heat but if you disagree simply add that cost.

For example, I live in a single-family residence heated with an efficient natural gas furnace. In my opinion one of the disadvantages of heat pump technology is that the output heat is relatively low compared to a combustion sourced furnace. The temperature at the register for a heat pump system is around 90°F whereas in my house the duct output temperature is around 120°F. However there some cold rooms in my house even when the furnace if providing hot air despite my best attempts to adequately insulate and reduce air infiltration. My house is in plant hardiness zone 5b so I believe that in order to maintain safety and comfort throughout the entire winter my house would need improved thermal insulation, spots where there are thermal bridges would have to be fixed, airtightness improved, my double-glazed windows replaced with triple glazed windows, and a heat recovery exchange system would have to be installed which means a deep shell installation. I live in a suburb where I don't believe that a ground source heat pump has enough yard space for installation so the Climate Act option is an air source heat pump. According to the Integration Analysis the cost per device to replace my existing efficient gas-fired furnace is $3,085. In order to provide backup heat, the cost of electric resistance heat also has to be added to the cost of the air source heat pump. The cost differential is in the deep shell, single family, ASHP column on the efficient gas furnace row. The expected cost to replace my natural gas furnace with an air source heat pump would be $57,869. Note that for a "basic shell" upgrade the cost is "only" $19,142, $38,727 less.

The spreadsheet tab also includes an estimate of the state-wide costs. Using the Bldg Res Stock tab device numbers and the costs from the main body table differential costs, I calculated the statewide costs. Note that I assumed that all building shells were upgraded to simplify the calculation by just splitting the reference shell total evenly between basic and deep. For the Integration Analysis distribution of basic and deep building shells the differential cost statewide cost projection is $259.3 billion. Using what I believe to be the most realistic distribution of building shells the projected statewide cost for retrofit home heating electrification is $318.5 billion.

## Table 6: Inputs Assumptions Workbook Residential Home Heating Electrification Costs

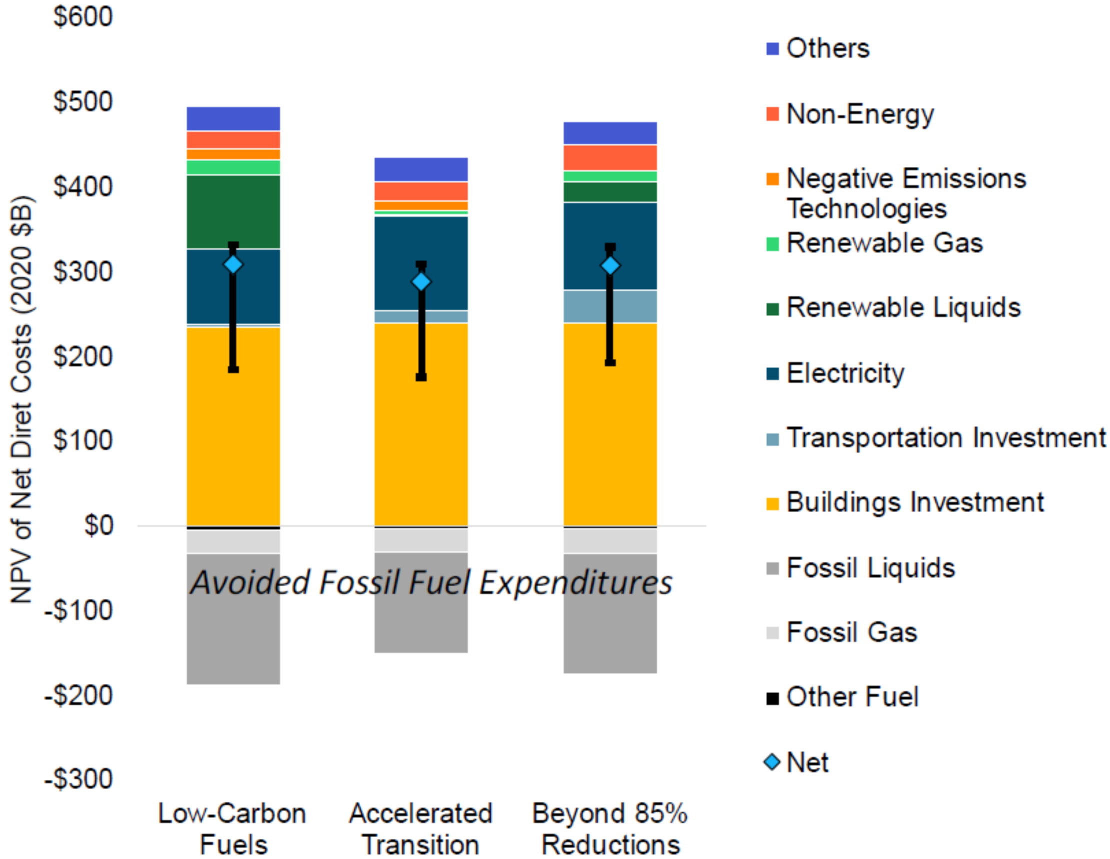
| | | | Basic Shell | | | | | | Deep Shell | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Single Family | | Small Multi Family | | Large Multi Family | | Single Family | | Small Multi Family | | Large Multi Family | |
| | | | ASHP | GSHP | ASHP | GSHP | ASHP | GSHP | ASHP | GSHP | ASHP | GSHP | ASHP | GSHP |
| Component Costs and Total Electrification Estimate | Air Source Heat Pump | $/device | $ 14,678 | | $ 13,643 | | $ 26,873 | | $ 14,678 | | $ 13,643 | | $ 26,873 | |
| | Electric Resistance | | $ 1,140 | | $ 1,140 | | $ 1,140 | | $ 1,140 | | $ 1,140 | | $ 1,140 | |
| | Ground Source Heat Pump | | | $ 34,082 | | $ 25,515 | | $ 39,974 | | $ 34,082 | | $ 25,515 | | $ 39,974 |
| | Building Shell | | $ 6,409 | $ 6,409 | $ 13,011 | $ 13,011 | $ 22,669 | $ 22,669 | $ 45,136 | $ 45,136 | $ 41,353 | $ 41,353 | $ 32,775 | $ 32,775 |
| | Reference Shell | | $ - | $ - | $ 6,723 | $ 6,723 | $ 3,590 | $ 3,590 | $ - | $ - | $ 6,723 | $ 6,723 | $ 3,590 | $ 3,590 |
| | Shell Differential | | $ 6,409 | $ 6,409 | $ 6,288 | $ 6,288 | $ 19,079 | $ 19,079 | $ 45,136 | $ 45,136 | $ 34,631 | $ 34,631 | $ 29,185 | $ 29,185 |
| | Heating Electrification Total | | $ 22,227 | $ 40,491 | $ 21,071 | $ 31,803 | $ 47,092 | $ 59,053 | $ 60,954 | $ 79,218 | $ 49,414 | $ 60,146 | $ 57,198 | $ 69,159 |
| Single Family | Distillate Boiler | $ 9,260 | $ 12,967 | $ 31,231 | | | | | $ 51,694 | $ 69,958 | | | | |
| | Distillate Furnace | $ 4,190 | $ 18,037 | $ 36,301 | | | | | $ 56,764 | $ 75,028 | | | | |
| | Efficient Distillate Boiler | $ 11,585 | $ 10,642 | $ 28,906 | | | | | $ 49,369 | $ 67,633 | | | | |
| | Efficient Distillate Furnace | $ 6,515 | $ 15,712 | $ 33,976 | | | | | $ 54,439 | $ 72,703 | | | | |
| | Efficient Gas Boiler | $ 8,975 | $ 13,252 | $ 31,516 | | | | | $ 51,979 | $ 70,243 | | | | |
| | Efficient Gas Furnace | $ 3,085 | $ 19,142 | $ 37,406 | | | | | $ 57,869 | $ 76,133 | | | | |
| | Gas Boiler | $ 7,645 | $ 14,582 | $ 32,846 | | | | | $ 53,309 | $ 71,573 | | | | |
| | Gas Furnace | $ 2,705 | $ 19,522 | $ 37,786 | | | | | $ 58,249 | $ 76,513 | | | | |
| | Hybrid Oil Electric Heat Pump | $ 14,678 | $ 7,549 | $ 25,813 | | | | | $ 46,276 | $ 64,540 | | | | |
| | Hybrid Gas Electric Heat Pump | $ 14,678 | $ 7,549 | $ 25,813 | | | | | $ 46,276 | $ 64,540 | | | | |
| | LPG Furnace | $ 4,190 | $ 18,037 | $ 36,301 | | | | | $ 56,764 | $ 75,028 | | | | |
| | Wood Stoves | $ 7,550 | $ 14,677 | $ 32,941 | | | | | $ 53,404 | $ 71,668 | | | | |
| Small Multi Family | Distillate Boiler | $ 9,260 | | | $ 11,811 | $ 22,543 | | | | | $ 40,154 | $ 50,886 | | |
| | Distillate Furnace | $ 4,190 | | | $ 16,881 | $ 27,613 | | | | | $ 45,224 | $ 55,956 | | |
| | Efficient Distillate Boiler | $ 11,585 | | | $ 9,486 | $ 20,218 | | | | | $ 37,829 | $ 48,561 | | |
| | Efficient Distillate Furnace | $ 6,515 | | | $ 14,556 | $ 25,288 | | | | | $ 42,899 | $ 53,631 | | |
| | Efficient Gas Boiler | $ 8,975 | | | $ 12,096 | $ 22,828 | | | | | $ 40,439 | $ 51,171 | | |
| | Efficient Gas Furnace | $ 3,085 | | | $ 17,986 | $ 28,718 | | | | | $ 46,329 | $ 57,061 | | |
| | Gas Boiler | $ 7,645 | | | $ 13,426 | $ 24,158 | | | | | $ 41,769 | $ 52,501 | | |
| | Gas Furnace | $ 2,705 | | | $ 18,366 | $ 29,098 | | | | | $ 46,709 | $ 57,441 | | |
| | Hybrid Oil Electric Heat Pump | $ 13,643 | | | $ 7,428 | $ 18,160 | | | | | $ 35,771 | $ 46,503 | | |
| | Hybrid Gas Electric Heat Pump | $ 13,643 | | | $ 7,428 | $ 18,160 | | | | | $ 35,771 | $ 46,503 | | |
| | LPG Furnace | $ 4,190 | | | $ 16,881 | $ 27,613 | | | | | $ 45,224 | $ 55,956 | | |
| | Wood Stoves | $ 7,550 | | | $ 13,521 | $ 24,253 | | | | | $ 41,864 | $ 52,596 | | |
| Large Multi Family | Distillate Boiler | $ 9,260 | | | | | $ 37,832 | $ 49,793 | | | | | $ 47,938 | $ 59,899 |
| | Distillate Furnace | $ 4,190 | | | | | $ 42,902 | $ 54,863 | | | | | $ 53,008 | $ 64,969 |
| | Efficient Distillate Boiler | $ 11,585 | | | | | $ 35,507 | $ 47,468 | | | | | $ 45,613 | $ 57,574 |
| | Efficient Distillate Furnace | $ 6,515 | | | | | $ 40,577 | $ 52,538 | | | | | $ 50,683 | $ 62,644 |
| | Efficient Gas Boiler | $ 8,975 | | | | | $ 38,117 | $ 50,078 | | | | | $ 48,223 | $ 60,184 |
| | Efficient Gas Furnace | $ 3,085 | | | | | $ 44,007 | $ 55,968 | | | | | $ 54,113 | $ 66,074 |
| | Gas Boiler | $ 7,645 | | | | | $ 39,447 | $ 51,408 | | | | | $ 49,553 | $ 61,514 |
| | Gas Furnace | $ 2,705 | | | | | $ 44,387 | $ 56,348 | | | | | $ 54,493 | $ 66,454 |
| | Hybrid Oil Electric Heat Pump | $ 26,873 | | | | | $ 20,219 | $ 32,180 | | | | | $ 30,325 | $ 42,286 |
| | Hybrid Gas Electric Heat Pump | $ 26,873 | | | | | $ 20,219 | $ 32,180 | | | | | $ 30,325 | $ 42,286 |
| | LPG Furnace | $ 4,190 | | | | | $ 42,902 | $ 54,863 | | | | | $ 53,008 | $ 64,969 |
| | Wood Stoves | $ 7,550 | | | | | $ 39,542 | $ 51,503 | | | | | $ 49,648 | $ 61,609 |

**Comparison to Costs in Scoping Plan**

One of the biggest issues for the public and other stakeholders is costs. However, the cost documentation provided in the Draft Scoping Plan is completely inadequate as shown in Attachment 1 in this document. The Climate Act requires the Climate Action Council to "[e]valuate, using the best available economic models, emission estimation techniques and other scientific methods, the total potential costs and potential economic and non-economic benefits of the plan for reducing greenhouse gases, and **make such evaluation publicly available**" in the Scoping Plan (my emphasis added). The fact that the only description of the net direct cost is a bar chart without a breakdown of the cost components clearly demonstrates that this Climate Act requirement has been ignored in the Draft Scoping Plan. For example, Figure 47 lists the net present value of net direct costs relative to the reference case over the period 2020- 2050. The buildings component of the three mitigation scenarios is between $200 and $300 billion but, given the absence of grid lines or even tick marks, further resolution is a guess. For comparison purposes I guess that the buildings component is $230 billion.

The numbers in this figure are relative to the reference case. For the residential heating sector, I assume that the retrofit costs (heat pump costs minus replacement of existing electric heating appliances) represent this relative cost. My estimate does not include the costs of cooking, hot water, and washing/drying appliances or the entire commercial buildings sector. Therefore, there is a significant difference between the Draft Scoping Plan and my estimates of just residential sector home heating. Relative to Figure 47's building sector $230 billion projection, I estimated $295 billion in the simple estimate and $259.3 billing for my differential cost estimate. Importantly, using a more realistic estimate of building shell requirements as a function of climate zones my simple estimate approach projects a cost of $370.1 billion and the differential cost estimate projects $318.5 billion. In all cases my estimates of the residential electric heating costs relative to the reference case exceed the values in Figure 47.

**Figure 47. Net Present Value of Net Direct Costs Relative to Reference Case (2020-2050)**




**What should be provided**

For the remainder of 2022 the Climate Action Council will consider the feedback received as it continues to "discuss and deliberate on the topics in the Draft". It is my understanding that technical workshops are also planned. Given the importance of affordability and the widespread impact to every household I recommend that one of these sessions address the specifics of home electrification. As shown in these comments, a few assumptions have an out-sized impact on the estimated costs. The public deserves the opportunity to understand exactly how the Draft Scoping Plan cost projections were derived.

In any event additional numerical documentation is needed. While some aspects of the cost projections are documented in the Integration Analysis spreadsheets, there are critically important numbers missing. Moreover, the calculation flow is not documented well enough to reproduce the cost projections. It is unacceptable that the component costs in Figure 47 are not provided.

The residential home heating retrofit component of building costs discussed in these comments are a good example of what should be provided for a publicly available evaluation. In the examples included from the attached spreadsheet, estimated costs were based on totals across the period 2020-2050. The annual number of installations and device costs are listed so I presume that the Integration Analysis calculates annual costs and sums for the total. In addition to a list of tabs within the documentation spreadsheets, the flow of data between table calculations should also be summarized.

Other additional information is needed. Consider the following examples. I suspect that the device costs vary over time but there is no documentation. Any other values that change with time should also be documented. Building shell assumptions and values used are particularly important given their out-sized impact on the final costs. What was the rationale for the values used? Was there an uncertainty analysis of the effect of these assumptions? How were the building shell assumptions used to estimate air and ground source heat pump distributions? How were mobile homes addressed? How many residences were deemed inappropriate for heat pumps? What is the technology expected for those residences in the future?

I recommend that the Climate Action Council have a technical workshop that focuses on home electrification. It is important that this workshop explain how the Integration Analysis calculated all the numbers presented. An opportunity for stakeholders to provide questions beforehand to be addressed at the workshop would be appropriate as well as the chance for stakeholders to ask clarifying questions during the workshop itself. The emphasis should be on the exchange of technical information without any opportunity for personal comments. Throughout the implementation process to date, only one side of the transition challenge has been heard. It is time to open up the discussion.

**Conclusion**

In my opinion, home electrification is a primary concern for New Yorkers given the importance of affordability and the widespread impact to every household. Accordingly, I spent a lot of time trying to replicate the costs to retrofit existing furnaces with heat pumps. I found that the existing documentation is unacceptable.

The Climate Act requires the Climate Action Council to "[e]valuate, using the best available economic models, emission estimation techniques and other scientific methods, the total potential costs and potential economic and non-economic benefits of the plan for reducing greenhouse gases, and **make such evaluation publicly available**" in the Scoping Plan (my emphasis added). The fact that the only description of net direct costs is a bar chart without a breakdown of the cost components clearly demonstrates that this Climate Act requirement has been ignored in the Draft Scoping Plan.

In addition, there is a Public Service Commission mandate that needs to be considered. Public Service (PBS) CHAPTER 48, ARTICLE 4, § 66-p. Establishment of a renewable energy program (4) states:

> The commission may temporarily suspend or modify the obligations under such program provided that the commission, after conducting a hearing as provided in section twenty of this chapter, makes a finding that the program impedes the provision of safe and adequate electric service; the program is likely to impair existing obligations and agreements; and/or that there is a significant increase in arrears or service disconnections that the commission determines is related to the program.

All of the material described in the previous section "What needs to be provided" must be publicly available to fulfill the obligations of the Climate Act and ensure that cost information necessary to determine whether PSC mandates are met. The Integration Analysis documentation has to be supplanted and the Draft Scoping Plan needs to be revised to specifically address these obligations.

**Personal Information**

I am a retired electric generation utility meteorologist with nearly 40-years of experience analyzing the effects of environmental regulations on electric and gas operations.  The opinions expressed in these comments do not reflect the position of any of my previous employers or any other company I have been associated with, these comments are mine alone.

Roger Caiazza
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Citizens Guide to the Climate Act

**Attachment: Comparison to Costs in Scoping Plan**

One of the biggest issues for the public and other stakeholders is costs. However, the cost documentation provided in the Draft Scoping Plan is completely inadequate. Starting on page 80 the Draft Scoping Plan section 10.3 Key Benefit-Cost Assessment Findings describes costs. However, the primary technical documentation is in Appendix G: Integration Analysis Technical Supplement and two spreadsheets:

- Appendix G: Annex 1: Inputs and Assumptions [XLSX]
- Appendix G: Annex 2: Key Drivers and Outputs [XLSX]

This attachment lists all references to "direct costs" in the Appendix G text with my indented and italicized comments. I believe that it demonstrates the inadequacy of the cost documentation of the Draft Scoping Plan.

**Page 61:** Estimated system expenditures do not reflect direct costs in some sectors that are represented with incremental costs only. These include investments in industry, agriculture, waste, forestry, and non-road transportation.

> *No comment*

**Pages 64-68:** Integration Analysis Costs

> *This whole section is included because it is the primary documentation source for costs in the technical supplement.*

The integration analysis includes calculations for three different cost metrics: Net Present Value (NPV) of net direct costs, annual net direct costs, and system expenditure.

- NPV of Net Direct Costs: NPV of levelized costs in each scenario incremental to the Reference Case from 2020-2050. All NPV calculations assume a discount rate of 3.6%. This metric includes incremental direct capital investment, operating expenses, and fuel expenditures.
- Annual Net Direct Costs: Net direct costs are levelized costs in a given scenario incremental to the Reference Case for a single year snapshot. This metric includes incremental direct capital investment, operating expenses, and fuel expenditures.
- System Expenditure: System expenditure is an estimate of absolute direct costs (not relative to Reference Case). Estimates of system expenditure do not reflect direct costs in some sectors that are represented with incremental costs only. These include investments in industry, agriculture, waste, forestry, and non-road transportation.

> > *I don't have the appropriate background so cannot speak to the calculation choices for these different cost metrics. However, I have been unable to find any numerical documentation (e.g., spreadsheets) that support the estimated cost metric expenditures.*

Cost categories included in the metrics listed above are shown in Table 4.

**Table 4. Integration Analysis Cost Categories**

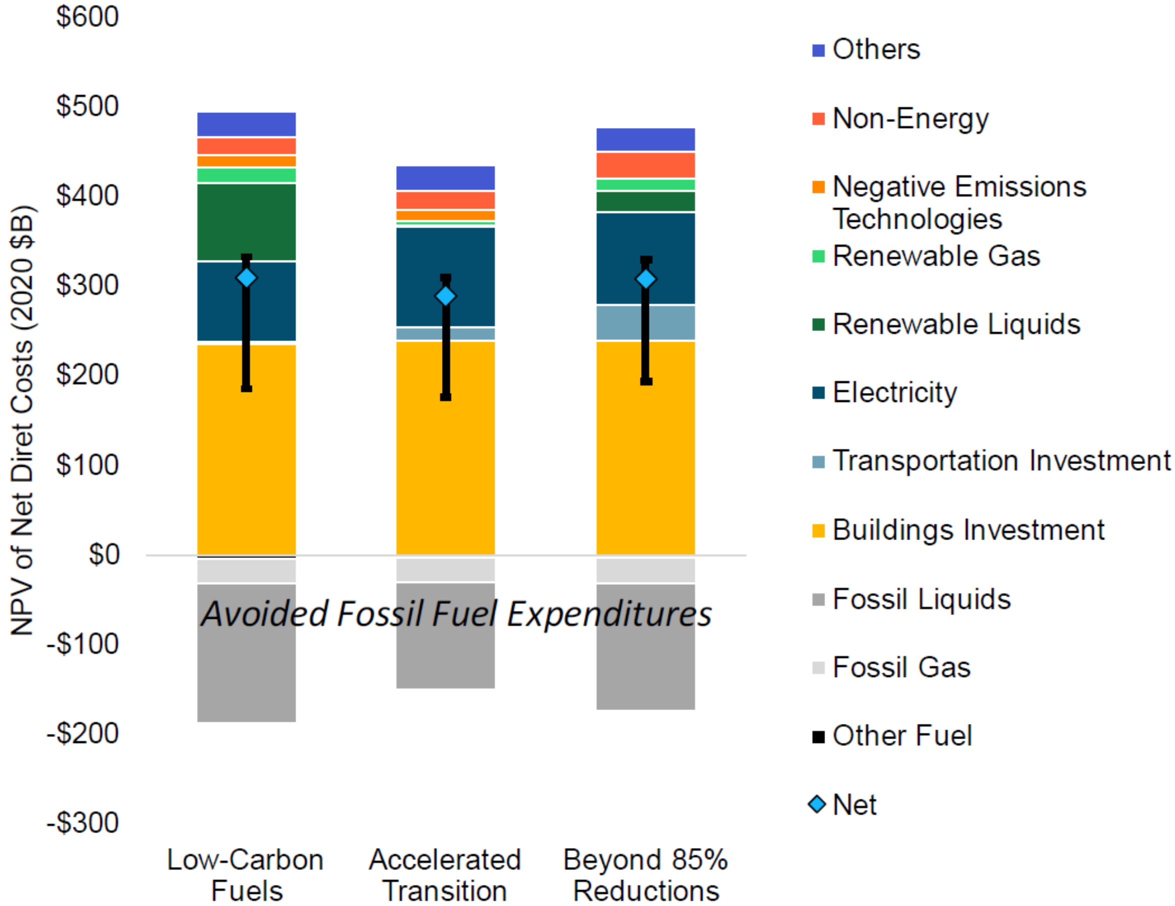
| Cost Category | Description |
|---|---|
| Electricity System | Includes incremental capital and operating costs for electricity generation, transmission (including embedded system costs), distribution systems, and in-state hydrogen production costs. |
| Transportation Investment | Includes incremental capital and operating expenses in transportation (e.g. BEVs and EV chargers) |
| Building Investment | Includes incremental capital and operating expenses in buildings (e.g. HPs and building upgrades) |
| Non-Energy | Includes incremental mitigation costs for all non-energy categories, including agriculture, waste, and forestry |
| Renewable Gas | Includes incremental fuel costs for renewable natural gas and imported green hydrogen |
| Renewable Liquids | Includes incremental fuel costs for renewable diesel and renewable jet kerosene |
| Negative Emission Technologies (NETs) | Includes incremental costs for direct air capture of CO2 as a proxy for NETs |
| Other | Includes other incremental direct costs including industry sector costs, oil & gas system costs, HFC alternatives, and hydrogen storage |
| Fossil Gas | Includes incremental costs spent on fossil natural gas (shown as a negative for cases when Gas expenditures are avoided compared with the Reference Case) |
| Fossil Liquids | Includes incremental costs spent on liquid petroleum products (shown as a negative for cases when liquids expenditures are avoided compared with the Reference Case) |
| Other Fuel | Includes incremental costs spent on all other fossil fuels |

*The spreadsheet Annex G: Inputs and Assumptions lists some of these costs and some of the assumptions made for these categories.*

The NPV of net direct costs in Scenarios 2, 3, and 4 are in the same range given uncertainty and are primarily driven by investments in buildings and the electricity system (Figure 47). All scenarios show avoided fossil fuel expenditures due to efficiency and fuel-switching relative to the Reference Case (shown in the chart as negative costs). Scenario 2: Strategic Use of Low-Carbon Fuels includes significant investment in renewable diesel, renewable jet kerosene, and renewable natural gas. Scenario 3: Accelerated Transition Away from Combustion meets emissions limits with greater levels of electrification, which results in greater investments in building retrofits, zero-emission vehicles, and the electricity system. Scenario 4: Beyond 85% Reductions includes additional investment in transportation (rail, aviation, VMT reductions) and methane mitigation, and mitigates the need to invest in any negative emissions technologies. Scenario costs are sensitive to the price of fossil fuels and technology cost projections, as reflected in error bars.

*In order to provide meaningful comments on these estimates much more information is needed. At an absolute minimum there should be a table that lists the values of the components of the Figure 47 bar charts. The Appendix G spreadsheet annexes document many of the figures in the Scoping Plan but none of the figures with direct costs are documented.*

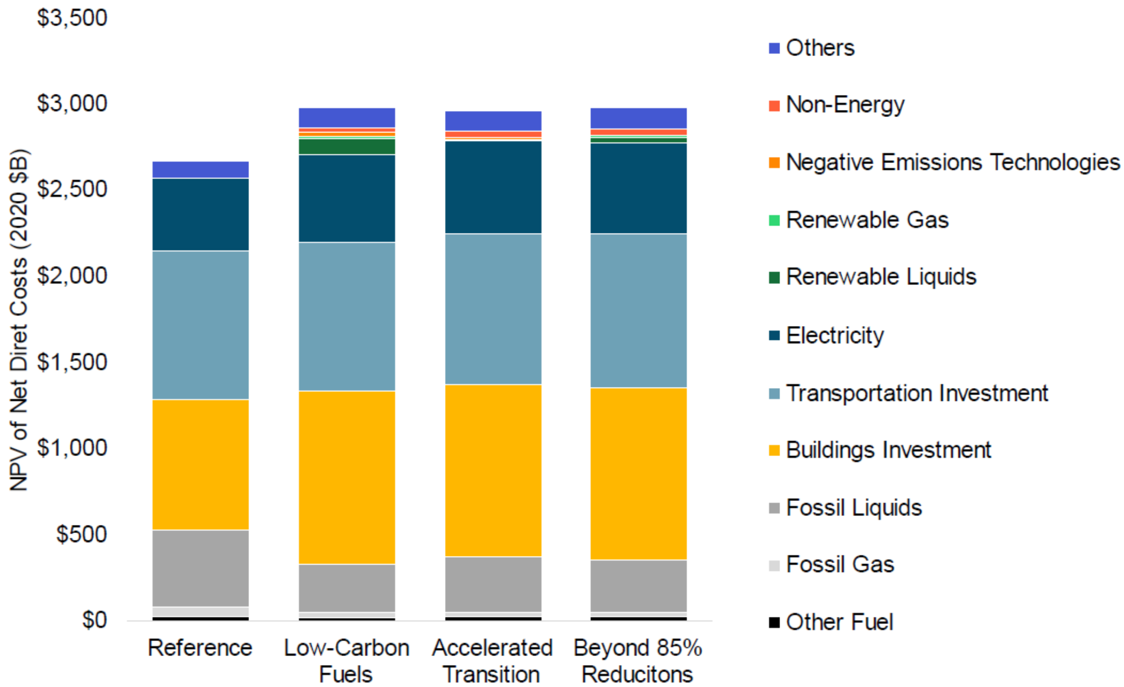
**Figure 47. Net Present Value of Net Direct Costs Relative to Reference Case (2020-2050)**




When viewed in from a systems expenditure perspective (Figure 48), the NPV of net direct costs for Scenarios 2, 3, and 4 are moderate, ranging from 11-12% as a share of the NPV of reference case system expenditures ($2.7 trillion). Because significant infrastructure investment will be needed to maintain business as usual infrastructure within the state irrespective of further climate policy, redirecting investment away from status quo energy expenditures and toward decarbonization is key to realizing the aims of the Climate Act.

*Not only are the Draft Scoping Plan Integration Analysis cost calculations undocumented but there is mis-leading reporting in this paragraph. These numbers represent the total costs of all their mitigation actions minus all the costs of a reference case. The statement "redirecting investment away from status quo energy expenditures and toward decarbonization is key to realizing the aims of the Climate Act" overlooks their estimate that status quo expenditures are already $2.7 trillion. There is no discussion whether that $2.7 trillion only represents current consumer costs or includes additional infrastructure spending. I expect that investments above and beyond what consumers are already are paying are needed so the actual consumer costs are being understated by this way of presenting the societal costs.*

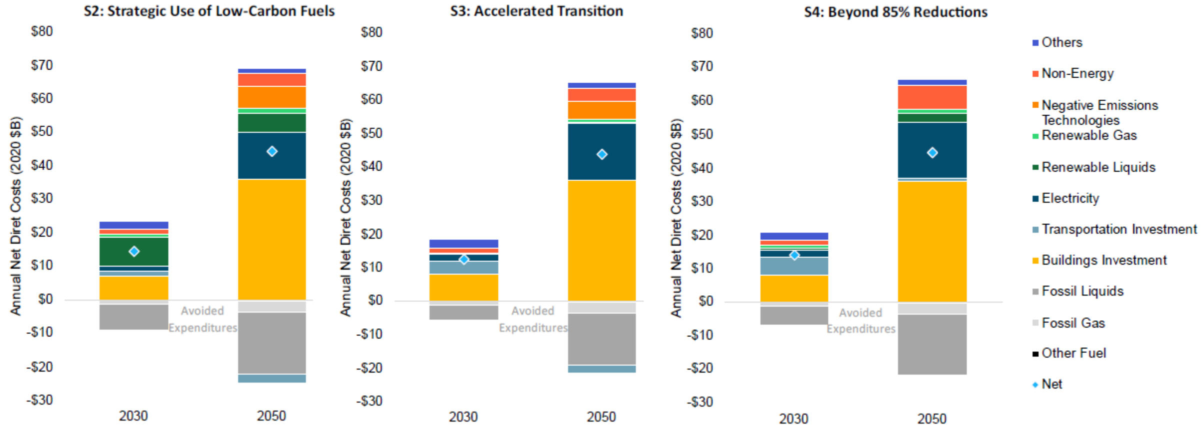
**Figure 48. Net Present Value of System Expenditures in Reference Case and Scenarios 2-4 (2020-2050)**




Annual net direct costs show the timing of key investments required to meet Climate Act emissions limits. Scenario 2 includes significant investment in renewable diesel, renewable jet kerosene, and renewable natural gas starting in the mid-2020s. Scenario 3 includes greater levels of electrification compared to Scenario 2, which results in greater investments in building retrofits, zero-emission vehicles, and the electricity system. Scenario 4 layers on even further investments in transportation and non-energy mitigation than Scenario 3 and includes a targeted investment in low-carbon renewable fuels, although not as intensive as that in Scenario 2. Both Scenarios 2 and 3 include investment in negative emissions technologies (NETs) to achieve net zero emissions by 2050, while Scenario 4 does not require any NETs to meet carbon neutrality by 2050. In 2030, annual net direct costs are on the order of $15 billion per year, approximately 0.6% of GSP; in 2050, costs increase to $45 billion per year, or roughly 1.4% of GSP.

*This represents the entirety of the description of the cost differences between the three scenarios. In order to provide full documentation, all the numbers associated with the assumptions used to derive the numbers have to be presented and they don't even list the component numbers of the bar charts. For example, consider NETs. Obviously, the final cost needs to be presented but we also need to know the costs per type of negative technology, the control efficiency expected, the number of these magical technology systems that do not exist at commercial scale that will be needed, and the assumed location assume for them because all those factors affect cost. I could find no reference to these technologies in the Appendix G appendices. Moreover, I have been unable to find the necessary documentation for any of the technologies proposed for the mitigation scenarios at a level where it is possible to provide meaningful comments.*

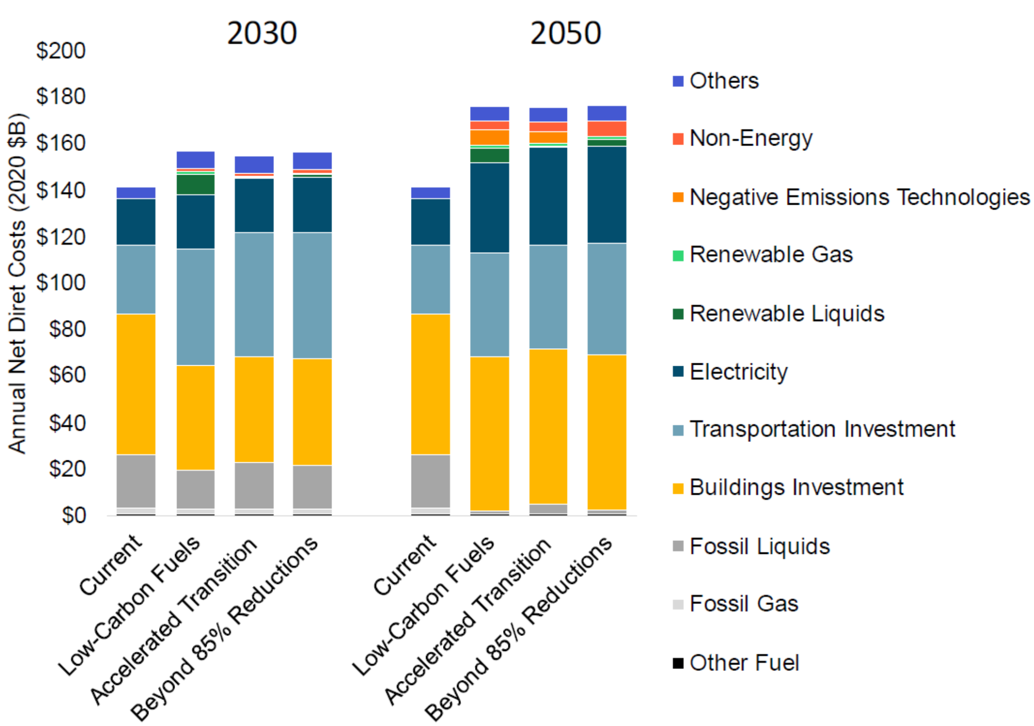
**Figure 49. Annual Net Direct Costs Relative to Reference Case in Scenarios 2-4**




Net direct costs are measured relative to the Reference Case, but system expenditures are evaluated on an absolute basis. System expenditures increase over time as New York invests in infrastructure and clean fuels to meet Climate Act emissions limits. As a share of overall system expenditures, costs are moderate: 9-11% in 2030 and 25-26% in 2050 relative to current estimated expenditure levels.

> *This figure also demonstrates the need for more information for meaningful comments. If the current system expenditures were documented then we could understand what is incorporated in their numbers. It would also be possible to verify their approach by comparing their estimates to other sources of data. It might also be possible to figure out whether their reference estimated expenditure costs represent increases to current levels.*

**Figure 50. Annual System Expenditures in Scenarios 2-4 (Compared to Current Expenditures)**



**Page 70:** Benefit-Cost Findings

- **Net direct costs are small relative to the size of New York's economy**. Net direct costs are estimated to be 0.6-0.7% of GSP in 2030, and 1.4% in 2050.

  *No comment*

**Page 70:** 3.5 Uncertainty and Sensitivity Analysis

There also are references to "direct cost" associated with the following figures in this section:

- Figure 52. NPV of Net Benefit of Mitigation Scenarios (2020-2050): Range Including Uncertainty in Fuel Cost, Technology Cost
- Figure 53. NPV of Scenario Net Direct Costs: Fuel cost sensitivity for Scenarios 2 through 4 For biofuels
- Figure 54. NPV of Scenario Net Direct Costs: Biofuel cost sensitivity for Scenarios 2 through 4
- Figure 55. NPV of Scenario Net Direct Costs: Technology cost sensitivity

  *This represents the Integration Analysis information that is supposed to address the concerns I raised here. Clearly without complete documentation it is impossible to agree or disagree that these cost sensitivities are complete or accurate.*

**Integration Analysis Documentation**

The Integration Analysis technical documentation is in Appendix G: Integration Analysis Technical Supplement and two spreadsheets:

- Appendix G: Annex 1: Inputs and Assumptions [XLSX]
- Appendix G: Annex 2: Key Drivers and Outputs [XLSX]

This section describes the cost information provided in these spreadsheets.

As noted previously, neither spreadsheet documents the numbers presented in Figures 45-55 in Appendix G: Integration Analysis Technical Supplement. In addition, there is insufficient information to determine how the numbers were calculated as shown in my comments on residential heating electrification. Some of the assumed technology costs are included but there are gaps in either information or methodology that prevent replication of the values presented. Consequently, it is impossible to provide substantive comments on the costs claimed.

**Conclusion**

The Climate Act requires the Climate Action Council to "[e]valuate, using the best available economic models, emission estimation techniques and other scientific methods, the total potential costs and potential economic and non-economic benefits of the plan for reducing greenhouse gases, and **make such evaluation publicly available**" in the Scoping Plan (my emphasis added). The fact that the only description of the net direct cost is a bar chart without a breakdown of the cost components clearly demonstrates that this Climate Act requirement has been ignored in the Draft Scoping Plan.