

SMARTargets

A Methodology for Grounded and Actionable Climate Targets
Aligned with Global Goals



APPENDIX B: SMARTARGETS METHODOLOGY IMPLEMENTATION ILLUSTRATIVE EXAMPLES

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Appendix B: Illustrative Implementation Examples

Introduction

This appendix provides examples of applying the SMARTargets Methodology to emissions categories relevant for electricity generation, transmission and distribution, and natural gas utilities. The scenario designs and analyses provided in this appendix are illustrative examples of how the methodology can be used to inform target setting, strategy development, risk management, and communications. The examples are intended as proofs of concept for the methodology, with results that are not intended to be applied to any specific company. Actual implementation by an individual company would entail company-specific consideration of practical issues, scenario design (e.g., reference and uncertainty conditions considered), modeling implementation, analysis, and decisions.

In each illustrative example, a transition risk scenario design is used to evaluate transition uncertainty relevant to identifying possible emissions futures, infrastructure and activity transitions, implications, and risks for targets. The target evaluation and setting approaches taken vary between the examples due to differences in uncertainties, greenhouse gas (GHG) sources, abatement options, and analytical needs.

For each example, we provide a brief overview and then work through the eight SMARTargets Methodology steps (Figure B1). For Steps 2 and 4, we walk through the process, as well as provide illustrative results, for considering practical issues and developing a transition risk analysis respectively.

- 1 **STEP 1: GHG inventories and base year**
- 2 **STEP 2: Practical issues and climate target groupings**
- 3 **STEP 3: Aspirational climate targets aligned with international goals**
- 4 **STEP 4: Company transition risk analysis of opportunities and risks**
- 5 **STEP 5: Strategy and qualified target alignment with international goals**
- 6 **STEP 6: Documentation and communication**
- 7 **STEP 7: Validation and verification**
- 8 **STEP 8: Monitoring and adjusting**

Figure B1. The SMARTargets Methodology implementation steps

Recall that a utility needs to apply the methodology to each of the emissions categories listed in Table B1. However, the company is free to set targets by emissions category, by GHG across categories, or across GHGs and categories. The illustrative examples in this appendix focus on target setting for emissions associated with the services provided by each type of utility—electricity generation, transmission and distribution, and gas supply. A utility that provides multiple services, would need to consider analyses similar to that shown for the emissions targets for the individual services.

Table B1. Emissions categories a utility needs to consider for target setting

Source: EPRI using WRI/WBCSD (2004, 2011).

Scope 1
Direct Emissions from Stationary Combustion
Direct Emissions from Mobile Combustion
Direct Emissions from Process Sources
Direct Emissions from Fugitive Sources
Scope 2
Indirect Emissions from Purchased/Acquired Electricity
Indirect Emissions from Purchased/Acquired Steam
Indirect Emissions from Purchased/Acquired Heating
Indirect Emissions from Purchased/Acquired Cooling
Scope 3
Category 3: Fuel- and energy-related activities (not included in scope 1 or scope 2)
Category 11: Use of sold products

Modeling description

For the examples in this appendix, we implement regional economy-wide modeling for a single region of the United States (U.S.). The regional modeling provides strategic perspectives regarding potential economy-wide and sector-wide decarbonization transitions and risks. Evaluating economy-wide transitions sub-nationally at the regional level allows us to capture and evaluate the implications of the unique regional endowments, markets, and low-carbon options that define decarbonization transition opportunities (EPRI, 2023). Specifically, for the examples, we run EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy Model (US-REGEN) and generate transition results for a variety of energy system, economic, and environmental variables. In each example, we share a sample of results to illustrate the approach and types of information produced. US-REGEN is a framework for evaluating the economic and environmental impacts of national and regional policies. It combines a detailed dispatch and capacity expansion model of the United States and regional electric sectors with technologically detailed consumer choice models of end-use services, technology choices, and energy demands and markets, including fuel markets.¹ As needed, for some GHG categories, we also show how GHG abatement supply resources can be incorporated into the analysis to provide target setting insights.

¹ For US-REGEN model documentation, see <https://us-regen-docs.epri.com/>. Numerous analyses have been published recently using the US-REGEN model, including Bistline et al. (2023), EPRI (2023), Blanford et al (2022), Bistline et al. (2022), and EPRI (2022b).

Illustrative results for electricity generation emissions targets

This example illustrates the derivation of SMARTargets for electricity generation CO₂ emissions for a hypothetical company that generates electricity and purchases electricity to serve load. GHG emissions associated with generating electric power are CO₂ emissions due primarily to the stationary combustion of fossil fuels. As such, the company is most concerned with the following two emissions categories (Table B1):

1. Direct own stationary combustion CO₂ and
2. Indirect purchased electricity CO₂.

The example is based on a U.S. Midwestern region and the hypothetical company sits within the region and is interested in understanding how their sector and economy might evolve with decarbonization by 2050 and what might be the implications and risks. Using US-REGEN, we can constrain emissions and evaluate the implications of alternative potential regional low-carbon transitions for electricity supply and investments, electricity demand, energy demand, fuel markets, and emissions.

Below, we describe how this electricity generation utility would apply each step of the SMARTargets Methodology.

Step 1: GHG inventories and base year

Step 1 Outputs: Verified GHG inventory and emissions reductions base year.

The first step is for a company to assemble their GHG inventory and select a base year. A company will need GHG emissions accounts for each of the categories of emissions relevant to their business. A company will also need to decide on their emissions reduction base year and apply it consistently. Note that the company will need to have the inventories verified.

For this example, Table BE1 summarizes the emissions for our illustrative utility. The primary source of emissions is own generation, however, indirect emissions from purchased power are also noteworthy. The utility could have other emission sources but, for this example, we assume they represent only a small fraction of the overall inventory.

The emissions trend is illustrated in Figure BE1. As shown, emissions over the last decade have been declining. An analysis of the emissions drivers reveals that this is primarily due to shifts away from fossil fuel electricity generation over the period shown.

Table BE1. GHG inventory for key categories in electricity generation illustrative example

Source: EPRI using EPA (2024) and illustrative GHG corporate inventories.

Key emissions categories	2015 (base year)	2021 (most recent)
	MMtonCO _{2e}	
Direct stationary combustion CO ₂	66.0	50.2
Indirect purchased electricity CO ₂	16.0	12.2

Given the information available, we assume the utility decides to select 2015 as its base year. This decision is based on considering the accuracy of their inventories, the inventory years verified, and choosing a year that facilitates communications regarding the utility's emissions trends.

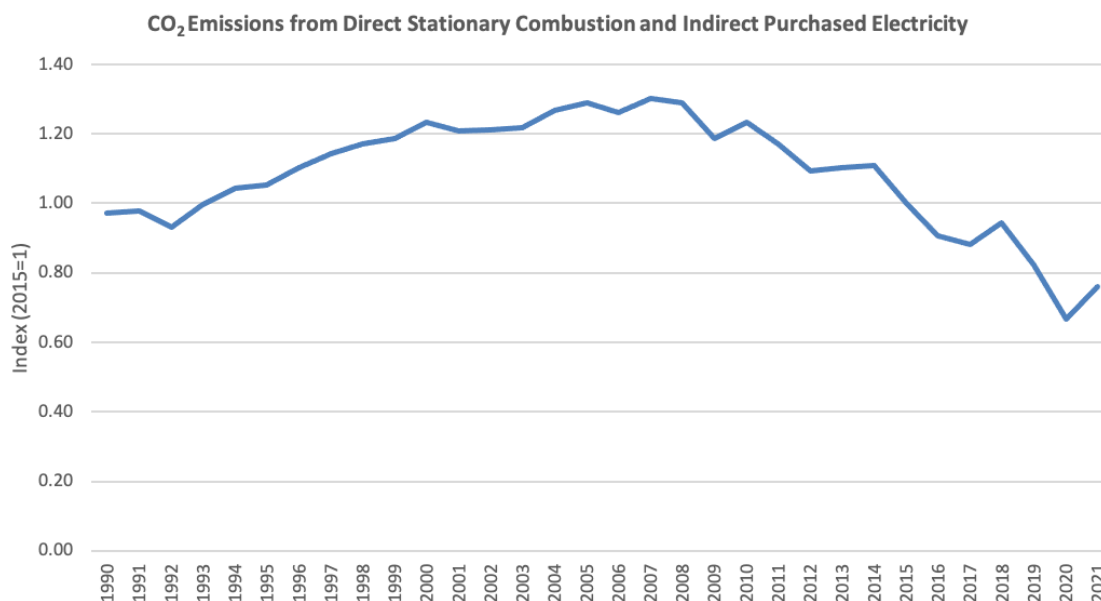


Figure BE1. Emissions trend for electricity generation illustrative example

Step 2. Practical issues and climate target groupings

Step 2 Outputs: Decisions on practical issues, including emissions categories covered (by regulation or company targets), the categories for which targets are being set, and how these categories are grouped for target evaluation.

For this step, our illustrative utility works through the company target setting practical issues, as well as identifies their target groupings. Table BE2 presents example responses to the set of practical issues questions for both emissions categories, and below we discuss the implications. This step helps companies assess practical considerations that may influence their ability to set and achieve targets. The company's responses also inform their evaluation of targets (Step 4).

For each emissions category, the company decides whether to:

1. Set a target (using the subsequent SMARTargets steps),
2. Not set a target because the emissions are already covered by a Paris Agreement aligned policy or another company's Paris Agreement aligned targets,
3. Not set a target with justification based on practical considerations that currently preclude target setting, or
4. Not set a target because the category is not relevant to their business.

Table BE2. Illustrative practical issues responses for the primary electricity generation emissions categories

Company target setting practical considerations question	Response for own electricity generation emissions (Scope 1 Direct Emissions from Stationary Combustion)	Response for purchased electricity emissions (Scope 3 Category 3 Fuel and Energy Related Activities not in scopes 1 & 2)
Is the emissions category adequately estimated and reported?	Yes, the emissions can be adequately characterized	Yes, the emissions can be adequately characterized
Are the emissions material to the company's overall GHG inventory? (e.g., above 5% of total emissions or a threshold defined by the company)	Yes, the emissions from this source category represent the majority of our emissions	Yes, the emissions from this source category are greater than 5% of our emissions
Are the category's emissions regulated by a Paris Agreement aligned policy?	No, the emissions from this source category are not currently regulated	No, the emissions from this source category are not currently regulated
Does another company in the value chain already set Paris Agreement-aligned targets for this source? (applicable only to indirect emission sources)	n/a – direct emissions category	Yes, the source category does currently have targets, which include 50% reductions by 2030 relative to 2005 and net-zero by 2050. These targets are aligned with the global pathways consistent with the Paris Agreement goals (see Step 5).
Does the company have control or influence over the emissions?	Yes, for the most part, we control the emissions, including dispatch decisions	Partially, we can decide from whom we purchase power but we are also constrained by clean power availability

Based on the responses in Table BE2, the company should consider pursuing targets for both their own and purchased power generation CO₂ emissions. Another electricity generating company might have different responses to some of the questions or reach a different conclusion based on the responses in the table. For instance, some utilities do not have controlling ownership of the generation, or do not control the dispatch of their generating units; and, therefore, they do not control the operations and the emissions. In this case, they would want to consider the drivers of this uncertainty in their Step 4 transition risk analysis. Similarly, the generating emissions for some utilities are covered by current state regulations, such as in California or Minnesota in the U.S. In this case, the utility might choose not to set targets because setting a company target could complicate compliance with state regulations. Similarly, for purchased power, some companies lack control because the purchased electricity comes from the market and the emissions are determined by the system operator's dispatch of system units. The lack of control of the market mix of energy would be an important uncertainty to consider in the Step 4 analysis.

For this example, we assume the company decides to proceed with evaluating and pursuing targets for both categories and will therefore undertake subsequent steps, including the Step 4 analysis to evaluate the targets, transition opportunities and risks, and enabling conditions.

In this step, the company also needs to decide on its target groupings. For this example, we assume the company pursues a single CO₂ target that includes both of the CO₂ emissions categories. The companies overall target setting and target grouping decisions are documented in Table BE3.

1 Table BE3. Emissions category targets

2 Table note: Emissions categories are those from Table B1 * Emissions not relevant to business or no material to inventory.

Emissions category	GHG total (MtCO ₂ e or NA if not relevant to business)	Currently covered				To be covered by future Company SMARTargets (MtCO ₂ e)	Not Covered (MtCO ₂ e)	Justification (and, as relevant, plans for not covered emissions and future targets)
		By Our Current Company SMARTargets (MtCO ₂ e)	SMARTarget type (indicate if target for category, GHG, or CO ₂ e)	By Paris Agreement Aligned Regulation (MtCO ₂ e)	By Another Company's Paris Agreement Aligned Targets (MtCO ₂ e)			
Scope 1. Direct Emissions from Stationary Combustion	50.2	50.2	CO ₂					CO ₂ emissions from own generation resources are material
Scope 1. Direct Emissions from Mobile Combustion	0.1							Not material*
Scope 1. Direct Emissions from Process Sources	n/a							n/a
Scope 1. Direct Emissions from Fugitive Sources	0.2							Not material*
Scope 2. Indirect Emissions from Purchased/Acquired Electricity	0.3							Not material*
Scope 2. Indirect Emissions from Purchased/Acquired Steam	n/a							n/a
Scope 2. Indirect Emissions from Purchased/Acquired Heating	n/a							n/a
Scope 2. Indirect Emissions from Purchased/Acquired Cooling	n/a							n/a
Scope 3. Fuel- and energy- related activities (not included in scope 1 or 2)	12.2	9.3	CO ₂					CO ₂ emissions from purchased power are material, the rest of the emissions are related to upstream fuels activities and not material
Scope 3. Use of sold products	n/a							n/a

3

Step 3. Aspirational targets aligned with international goals

Step 3 Outputs: Aspirational targets that will be evaluated in the Step 4 transition risk analysis.

For this step, the utility will select generic Aspirational Targets (ATs) aligned with the international goals for their net CO₂ target covering owned and purchased electricity generation CO₂ emissions. The utility identifies intermediate and 2050 ATs using Table BE4, which shows the net CO₂ ATs from Table 6 of the methodology document. The utility must select a 2030 or 2035 intermediate AT, as well as a 2050 AT. They are also welcome to select additional pre-2050 intermediate targets using the table. For this example, we assume the utility chooses to select 2030 and 2040 intermediate ATs and therefore their set of ATs are -56%, -88%, and net-zero (-100%) from 2015 for 2030, 2040, and 2050.

Table BE4. Generic Aspirational Targets (% reduction from 2015)

	Net CO ₂
2030	-56%
2035	-82%
2040	-88%
2045	-94%
2050	-100%

Step 4. Company transition risk analysis of opportunities and risks

Step 4 Outputs: Company regional transition opportunities and risks, evaluation of aspirational and qualified targets and their enabling conditions, and transition strategies (low-carbon & risk management).

Given that the utility has decided to evaluate and pursue targets (Step 2), they will need to undertake transition risk analysis to identify their opportunities, risks, and risk management strategies for pursuing the Step 3 ATs and identifying qualified targets (QTs) and their associated conditions. The utility works through the seven phases associated with the transition risk analysis. The example analysis below informs aggregate net CO₂ targets across both own generation and purchased power CO₂ emissions.

Phase 1: Define reference conditions and itemize uncertainties

- Phase inputs: Previous company planning, strategy, analysis, and risk management experience
- Phase outputs: Scenario analysis reference conditions and list of uncertain factors to consider in scenario design
- Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as possibly external experts on scenario analysis and modeling
- Documentation: SMARTargets template summarizing reference conditions and uncertain transition factors for scenario design consideration

For this phase, the company works with their planning, policy, sustainability, risk management, strategy, and outreach staff, as well as any external experts on scenario analysis and modeling with which they choose to collaborate. Together, the team defines their scenario analysis reference conditions and the uncertain factors that they want to consider in their scenario design in Phase 2.

For reference conditions, the company develops lists for announced retirements, new builds underway for new capacity, and new builds underway for new transmission. All will be implemented as constraints in the modeling analysis. The model can retire or build more, but it will not be able to do less. The company might also include local or federal policy drivers that they want to include in every transition future they evaluate. For instance, there might be a state renewables goal of increasing wind and solar generation, or federal incentives for certain technologies. These would be incorporated as either modeling constraints such that the model can do more, but it cannot do less, or economic factors that change the relative and overall costs.

The company staff, and any experts involved, will also develop a list of uncertain factors that they believe are or could be important and that they want to evaluate in some way. In this case, we assume the company identifies the following uncertain factors:

- Electricity supply decarbonization options,
- Electricity supply technology cost and performance improvements,
- Future electricity demand (load),
- Low-carbon generation technology development and commercialization,
- Low-carbon generation technology permitting,
- Supply chain constraints related to low-carbon generation technologies,
- Not in my backyard (NIMBY) issues,
- Resource procurement,
- Support for new transmission infrastructure investments,
- New transmission infrastructure costs,
- New transmission siting and permitting,
- Fuel availability,
- Fuel pipeline capacity/augmentation, and
- End-use technology cost and performance improvements.

Note that the SMARTargets scenario design already accounts for uncertainty about the type of decarbonization—power sector only versus economy-wide. At the end of Phase 1, the utility will document their reference conditions and itemize the identified uncertain factors in the SMARTargets Reporting Template.

Phase 2: Create core scenario design – define plausible extreme alternative future conditions

- *Phase inputs: Phase 1 scenario analysis reference conditions and list of uncertain factors to consider in scenario design.*
- *Phase outputs: The company's core scenario design for the required SMARTargets scenarios.*
- *Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as possibly external experts on scenario analysis and modeling.*
- *Documentation after iterations: SMARTargets Reporting Template entries summarizing the core scenario design.*

For this phase, the company continues working with the same team as in Phase 1 to define their core scenario design for the required SMARTargets scenarios. Table BE5 presents the SMARTargets Methodology required AT and QT scenarios for electricity supply CO₂ emissions. For the Qualified Targets, the company will define increasing reduction levels for evaluation—X, Y, and Z%. The incremental

1 reductions will help the company identify their qualified CO₂ reduction targets without enabling
2 conditions. The specific X, Y, and Z% incremental reduction levels will be defined after the company
3 reviews the results from the AT scenarios and after the company has identified the AT enabling conditions.

4 To implement the Table BE5 AT scenarios, the company needs to define the future conditions—
5 Fuller/More Limited decarbonization option conditions and Facilitating/Challenging other conditions.
6 Table BE5 provides example definitions for each of these conditions. Recall, that the conditions should be
7 intentionally more extreme. Thus, the Fuller and More Limited decarbonization options sets differ
8 notably, with differences in the availability of advanced nuclear, fossil generation with and without CCS,
9 carbon dioxide removal, bioenergy, low-carbon imported power, and the opportunity to use fossil
10 resources to satisfy capacity reserve requirements.

11
12 Defining the Facilitating and Challenging other conditions consists of three intermediate steps: (1)
13 combining uncertain factors that have similar qualitative implications into uncertainty categories, (2)
14 combining categories into sets of conditions, and (3) defining the qualitative differences in the relative
15 conditions. The first, combining uncertain factors that have similar qualitative implications into
16 uncertainty categories, entails identifying uncertain factors with similar implications. Below are three
17 examples of sets of uncertain factors identified in Phase 1 that all affect the same condition:

- 18
19 - *Generation resource availability*: affected by technology development and commercialization;
20 permitting, supply chain, and not in my backyard (NIMBY) issues; and resource procurement.
- 21 - *Interregional transmission*: affected by support for infrastructure investments, costs, and siting
22 and permitting.
- 23 - *Fuel supply*: affected by resource availability and pipeline capacity/augmentation.

24
25 This grouping of uncertain factors into uncertainty categories allows the company to compactly
26 incorporate and capture many factors that can affect the same condition from the company's point of
27 view.

28
29 The outcome of the second phase, combining uncertainty categories into sets of conditions, is what is
30 shown in Table BE6. The set of uncertainties considered in both the Facilitating and Challenging conditions
31 includes uncertainty regarding electricity load growth, electricity generation cost improvements,
32 electricity capacity additions, electricity transmission additions, fossil fuel prices, and electric technology
33 cost improvements. Finally, the third step, defining the qualitative differences in the relative conditions,
34 requires specifying the relative condition differences for Facilitating and Challenging. For example, in
35 Table BE6, the alternative electricity generation cost improvement conditions are either faster or slower
36 cost improvements in Facilitating and Challenging respectively. Similarly, the alternative electricity
37 capacity additions conditions are economic versus constrained, where "constrained" refers to there being
38 non-economic constraints that slow the addition of new generation capacity more than what "economic"
39 conditions alone would allow.

40
41 With the scenario conditions defined, the company is ready for Phase 3 and quantification of the future
42 conditions. At the end of Phase 2, the company should document their definitions of Fuller/More Limited
43 and Facilitating/Challenging using the SMARTargets Reporting Template.

Table BE5. Required scenarios for evaluating reductions in electricity supply CO₂ emissions

Target type being evaluated	Target pathway	Economy-wide transition to net-zero in 2050	Decarbonization options	Other conditions
Reference	Reference (without CO ₂ constraint)	No	N/A	Facilitating
	Reference (without CO ₂ constraint)	No	N/A	Challenging
Aspirational Targets (net CO ₂ ATs and QTs > ATs)	Power sector transition to net-zero CO ₂ in 2050	No	Fuller	Facilitating
	Power sector transition to net-zero CO ₂ in 2050	No	More Limited	Challenging
	Power sector transition to net-zero CO ₂ in 2050	Yes	Fuller	Facilitating
	Power sector transition to net-zero CO ₂ in 2050	Yes	More Limited	Challenging
Qualified Targets (net CO ₂ QTs < ATs)	Power sector net CO ₂ transition to X, Y, and Z% in 2050	No	Fuller	Facilitating
	Power sector net CO ₂ transition to X, Y, and Z% in 2050	No	More Limited	Challenging

Table BE6. Illustrative Fuller/More Limited and Facilitating/Challenging decarbonization condition definitions

Illustrative FULLER decarbonization option set

Renewables (wind, solar, bio, hydro)
 Nuclear (extensions)
 Advanced nuclear (additions)
 Fossil
 Fossil w/CCS
 CDR (biopower w/ CCS & direct air capture (DAC))
 Storage
 Hydrogen
 Biopower carbon neutrality
 Other renewable fuels (w/ and w/o CCS)
 Low-carbon power imports
 Fossil capacity reserves permitted (within emissions constraint)
 Demand conservation and energy efficiency

Illustrative FACILITATING other conditions

Reference electricity load growth
Faster electricity generation cost improvements,
Economic electricity capacity additions,
Economic electricity transmission additions,
Lower fossil fuel prices,
Faster electric technology cost improvements

Illustrative MORE LIMITED decarbonization option set

Renewables (wind, solar, bio, hydro)
 Nuclear (extensions only)
 Storage
 Electrolytic Hydrogen only
 Other renewable fuels (w/ and w/o CCS)
 Fossil capacity reserve eligibility declines to zero in 2050
 Demand conservation and energy efficiency

Illustrative CHALLENGING other conditions

Faster electricity load growth
Slower electricity generation cost improvements,
Constrained electricity capacity additions,
Constrained electricity transmission additions,
Higher fossil fuel prices,
Slower electric technology cost improvements

Phase 3: Implement scenario design – specify assumptions for scenario modeling

- *Phase inputs: The company's Phase 2 core scenario design for the required SMARTargets scenarios.*
- *Phase outputs: Specification of core scenario design for the company's modeling framework.*
- *Who should be involved: Staff related to planning, sustainability, policy, and strategy, as well as external experts on scenario analysis, modeling, and alternative assumptions.*
- *Stakeholder engagement: This is a good time to seek external stakeholder feedback.*
- *Documentation after iterations: SMARTargets Reporting Template entries summarizing the core scenario design specification.*

For this phase, the company continues working with the same team as in Phases 1 and 2 to specify the core scenario design for implementation in their modeling framework. Phase 2 provides the company

with everything they need conceptually and qualitatively in terms of the scenarios they will run. Actually running the scenarios requires quantification of the scenario design. This includes specifying decarbonization technology cost and performance assumptions, as well as what exactly is meant by “faster” and “slower” cost improvements, and “constrained” capacity and transmission additions.

Tables BE7a and BE7b present an illustrative specification for each of the assumptions associated with the Fuller/More Limited and Facilitating/Challenging conditions. For the decarbonization technology assumptions, Table BE7a notes the technical resource. For the Facilitating and Challenging conditions, Table BE7b notes each specification. Remember that the specification definitions are intentionally extreme, but plausible, alternative conditions. They also need to be grounded, and justification should be provided for the specifications. For example, the higher load growth assumption for Challenging is based on recent data center growth trends and new analysis evaluating a potential higher growth future (EPRI, 2024).

The utility will also need to define the emissions constraint pathways they will be imposing on the model. These constraints will constrain the model to producing no more than the emissions reductions specified (though the model could produce emissions below the constraints).

After completing Phase 3 is a good time for external stakeholder feedback on the scenario design and specifications. It is an opportunity to discuss setting SMARTargets and the planned transition risk analysis and preliminary future conditions the company is considering. At the end of Phase 3, the company should document their specifications for their Fuller and More Limited decarbonization options, their Facilitating and Challenging conditions, and their emissions constraints in the SMARTargets Reporting Template.

Table BE7a. Illustrative summary of energy technology assumptions

Decarbonization technology cost and performance	Comment/description	Reference
Renewables (wind, solar, bio, hydro), nuclear, advanced nuclear, coal, coal w/ CCS, gas, gas w/ CCS, CDR (biopower w/ CCS, DAC), storage, hydrogen	Engineering-based cost and performance specifications with gradual improvement over time	EPRI (2022b)
Biomass carbon neutrality	Carbon neutral assumption based on analysis of net land use and GHG changes associated with increasing biomass supplies	Blanford et al (2022)
Other renewable fuels	Renewable liquid and gas fuels, including renewable gasoline, diesel, and jet fuel, renewable natural gas, and synthetic natural gas produce with renewable energy	Blanford et al (2022)
Low-carbon power imports	Low-carbon electricity can be exported to other regions via intra-regional transmission	EPRI (2023)
Fossil capacity reserves permitted (within emissions constraint)	Fossil generation capacity can be used to meet capacity reserve requirements but declining emissions constraints over time apply to any generation from that capacity	EPRI (2022b)

Demand conservation and energy efficiency	End-use sectors can reduce emissions through technology and fuel substitution that increases efficiency, as well as reductions in overall use	Blanford et al (2022)
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1 Table BE7b. Illustrative specifications for Facilitating and Challenging other condition assumptions

Other conditions	Facilitating	Challenging
Electricity load growth	Reference = load growth due to reference economic and population growth assumptions and electrification due to electric technology relative cost improvements	Faster = reference load growth conditions plus additional data center load growth based on recent trends resulting in 12% greater total load by 2030 (EPRI, 2024)
Electricity generation cost improvements	Faster = default cost projections and reference learning curve for battery cost improvements over time	Slower = higher cost projections by technology and slower learning curve for battery cost improvements over time
Electricity capacity additions	Economic = allows for all economically viable electric capacity to be built	Constrained = limits the building of economically viable electric capacity to historical build rates
Electricity transmission additions	Economic = allows for all economically viable interregional transmission to be built	Constrained = limits the building of economically viable interregional transmission based on historical transmission build rates
Fossil fuel prices*	Lower = No additional supply costs for fossil fuel production beyond the equilibrium cost determined by the energy economy model's balance of supply and demand for each fuel	Higher = Additional supply costs added to fossil fuel production modeling low resource availability or pipeline expansion
Electric technology cost improvements	Faster = Default cost reductions in EV & heat pump components, faster EV adoption reflective of less range anxiety and greater availability of new electric technologies	Slower = Higher component costs for EV & heat pumps, slower EV adoption representative of more range anxiety and less availability of new electric technologies

2 * The fossil fuel price assumptions in the table reflect the US-REGEN modeling structure. Other economy-wide
3 frameworks might have fixed assumed (i.e., exogenous) energy prices. For instance, they might be based on
4 lower/higher U.S. Department of Energy Annual Energy Outlook fuel price projections.

5 Phase 4: Identify potential transitions and target implications

- 6 ■ *Phase inputs: Phase 3 specification of core scenario design for implementation in the company's modeling framework.*
- 7
- 8 ■ *Phase outputs: Preliminary transition analysis pathways and insights.*
- 9 ■ *Who should be involved: Staff and external experts running the model and processing outputs.*
- 10 ■ *Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.*
- 11

12 For this phase, the company's staff, and any external experts, running the model and processing outputs
13 will work together to develop preliminary transition analysis pathway results and insights. The team will
14 be running the model with the scenario specification implementation developed in Phase 3, and they will

1 have to debug and likely revise the scenario specification implementation as they attempt to run each of
2 the scenarios in the design. They will also want to review the results for non-intuitive, or otherwise
3 problematic, outcomes that could be an artifact of an incorrect scenario specification or implementation.
4 The team will want to revise and rerun scenarios in these cases.

5 In addition to running the scenarios, the team will develop preliminary graphics—figures and tables—and
6 identify preliminary insights for review. In particular, the team will want to evaluate differences and
7 similarities in transition results between scenarios. The differences between the scenarios are the most
8 meaningful insights, not the specific values from individual scenarios. The differences will provide insights
9 regarding the direction and order of magnitude of the potential implications of the different conditions.
10 For instance, electricity supply utilities would be interested in the alternative potential transitions for
11 electricity capacity and generation mixes, electricity demand, power transmission, emissions, costs, and
12 prices. The modeling provides information regarding the alternative potential transitions, trade-offs,
13 uncertainty, risks, enabling conditions, robust strategies, contingencies, and more. Below we present
14 sample results for the company’s scenario design. For this example, recall that we are evaluating potential
15 market transitions for a company in the midwestern U.S. These results represent potential alternative
16 market and operational conditions for the company’s system and assets.

17 Figure BE2, for example, presents the electricity sector net CO₂ emissions transitions for the net-zero AT
18 scenarios. The figure includes the results for both the power only (“NZ electricity”) and economy-wide
19 (“NZ economy”) net-zero target scenarios. The power sector only targets reach 100% reductions (net-
20 zero) by 2050, with only slight variations in their cost-effective emissions transitions to 2050 due to the
21 different conditions.

22 Most importantly, we observe that the economy-wide net-zero policy facilitates more rapid emissions
23 reductions in the power sector than the sector only net-zero in 2050 target. Specifically, the economy-
24 wide net-zero scenarios are resulting in faster emissions reductions and possibly net-zero power by 2035.
25 This result is consistent with previous findings that an economy-wide policy incentivizes end-use
26 decarbonization and creates demand for low-carbon electricity that facilitates faster decarbonization of
27 the power sector (EPRI, 2022b; EPRI, 2022a). The faster decarbonization is enabled by the economy-wide
28 policy and the low-carbon electricity market it creates.

29 For a given decarbonization transition, power sector or economy-wide, the variation in transitions due to
30 the other conditions is most prominent in the physical energy infrastructure and economic implications.
31 Figures BE3, BE4, and BE5 present results for the four AT net-zero scenarios, and the two reference
32 scenarios, for electricity generation, load (demand), and generation capacity. First and foremost, the
33 figures immediately illustrate that there is significant transition uncertainty. This is shown by the large
34 variation across scenarios in the evolution of the generation and capacity portfolios over time. Thus, there
35 are very different plausible electricity generation, capacity, and load transitions consistent with a net-zero
36 by 2050 power system due to the different conditions. We also see significantly more capacity additions
37 in the AT futures, compared to the Reference futures (Figure BE4 and Figure BE5). Thus, significant
38 capacity additions are needed to meet the emissions constraints. The fastest and largest capacity
39 additions are with the economy-wide decarbonization transition due to the revenue provided by the
40 demand for low-carbon electricity across the economy. The higher electricity demand (load) in these
41 futures is evident in Figure BE3.

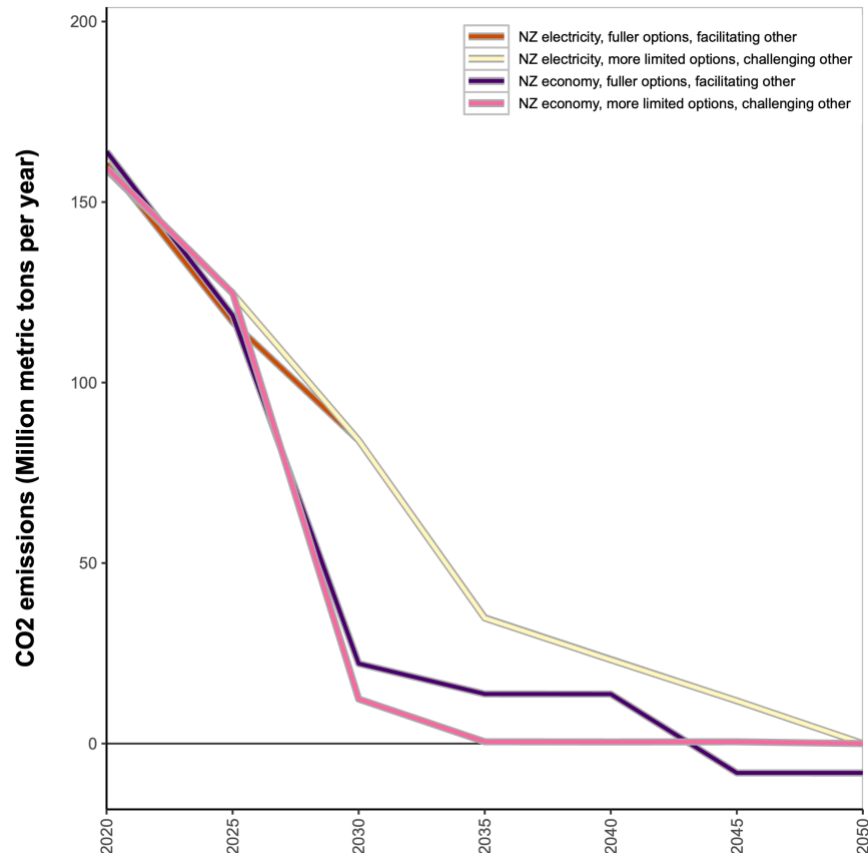


Figure BE2. Regional power sector net CO₂ emissions transitions

Source: EPRI analysis

We also observe important technology specific insights that help identify robust strategies and investment and operations uncertainty. Load increases, wind, solar, nuclear, and storage are key features in all four AT decarbonization transitions, as well as reference futures. As such, they would be robust strategies Figure BE5, in particular, illustrates that additions of wind, solar, and storage are consistent elements of all four AT futures, as is retirements of coal. However, we also see in Figure BE5 notable variation in the additions by 2035 and 2050, especially for solar, storage, and wind; and, mixed results for addition and retirement opportunities for gas, nuclear, and hydrogen, with only some conditions conducive to those investments. Overall, the cumulative capacity changes associated with all four futures are substantial but with large variation. By 2035, we find additions of approximately 100 to 195 GW and retirements of approximately 30 to 40 GW. By 2050, the additions and retirements are approximately 280 to 380 GW and 65 to 80 GW respectively. For comparison, in 2024, there was 60 GW of new capacity additions planned across the entire U.S., and 7.5 GW of capacity retirements planned (EIA, 2024). The reference futures alone suggest a good deal of cost-effective additions and retirements, with gas, wind, and hydrogen the primary capacity additions and coal the primary retired capacity (Figure BE5). Note that natural gas related resources are providing notable generation and/or capacity in all the net-zero decarbonization futures, with coal resources also in use through 2045 under some conditions, and the role and the magnitude of gas and coal resources over time varying substantially with the different conditions. In the four decarbonization futures, in 2035 and 2050, gas capacity could be 25 to 52 GW and 0 to 59 GW respectively, while coal capacity could be 1 to 8 GW and 0 to 1 GW respectively.

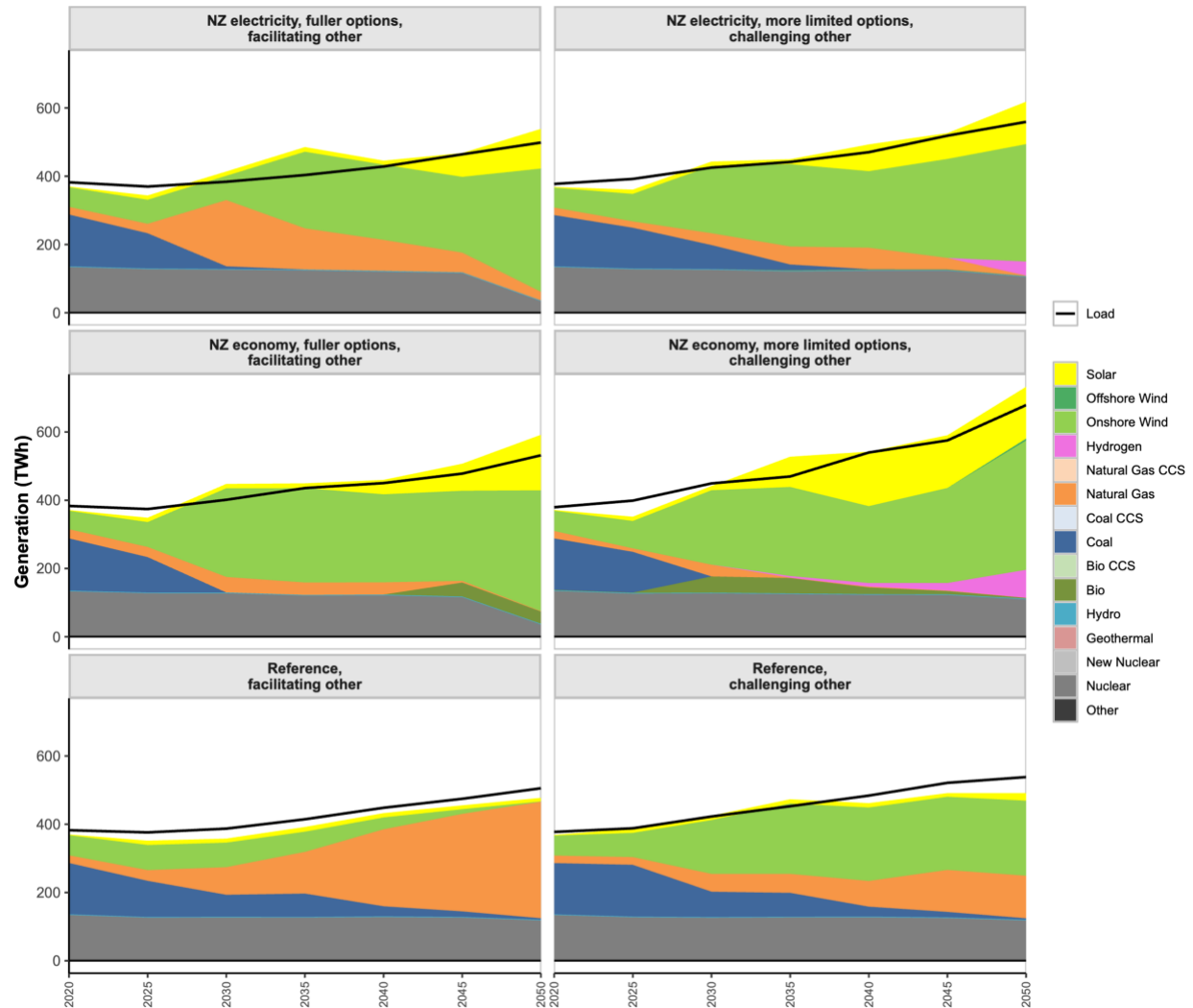


Figure BE3. Regional electricity generation and load transitions

Source: EPRI analysis

Figure note: Illustrative results for a Midwest region of the U.S. and for the illustrative scenario design and specification. Results will vary by region of the world and scenario design and specification. Top row results associated with net-zero CO₂ by 2050 power sector transitions with Fuller and More Limited decarbonization options available and Facilitating and Challenging market and technology conditions. Middle row results associated with net-zero CO₂ by 2050 economy-wide transitions with Fuller and More Limited decarbonization options available and Facilitating and Challenging market and technology conditions. Bottom row results associated with reference economy-wide transitions with Facilitating and Challenging market and technology conditions. Natural gas includes a mix of renewable and synthetic natural gas, and dual fuel capacity includes capacity using mixes of fossil and renewable fuels (gas and liquid).

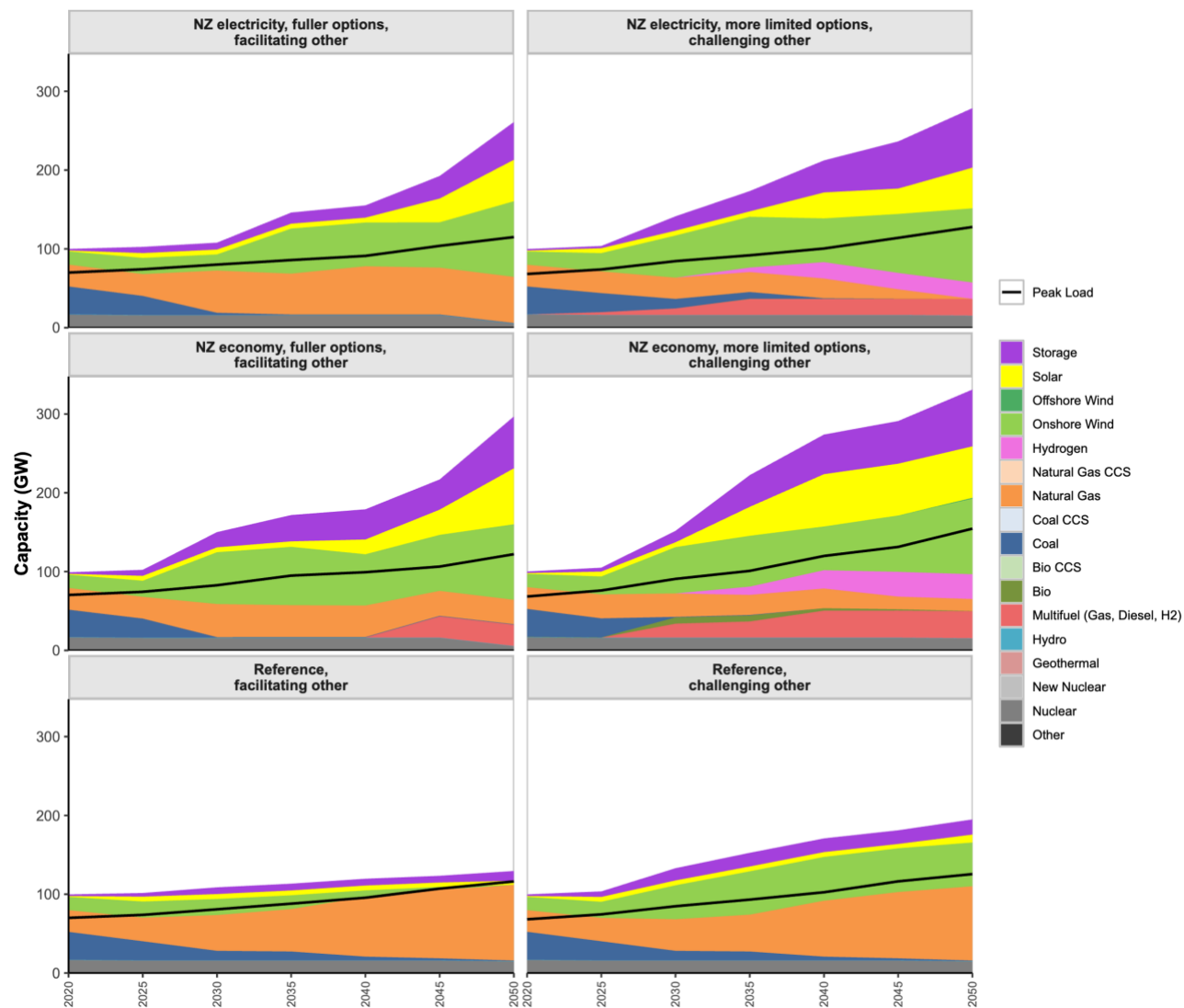


Figure BE4. Regional electricity generation capacity transitions

Source: EPRI analysis

Figure note: Figure BE3 note.

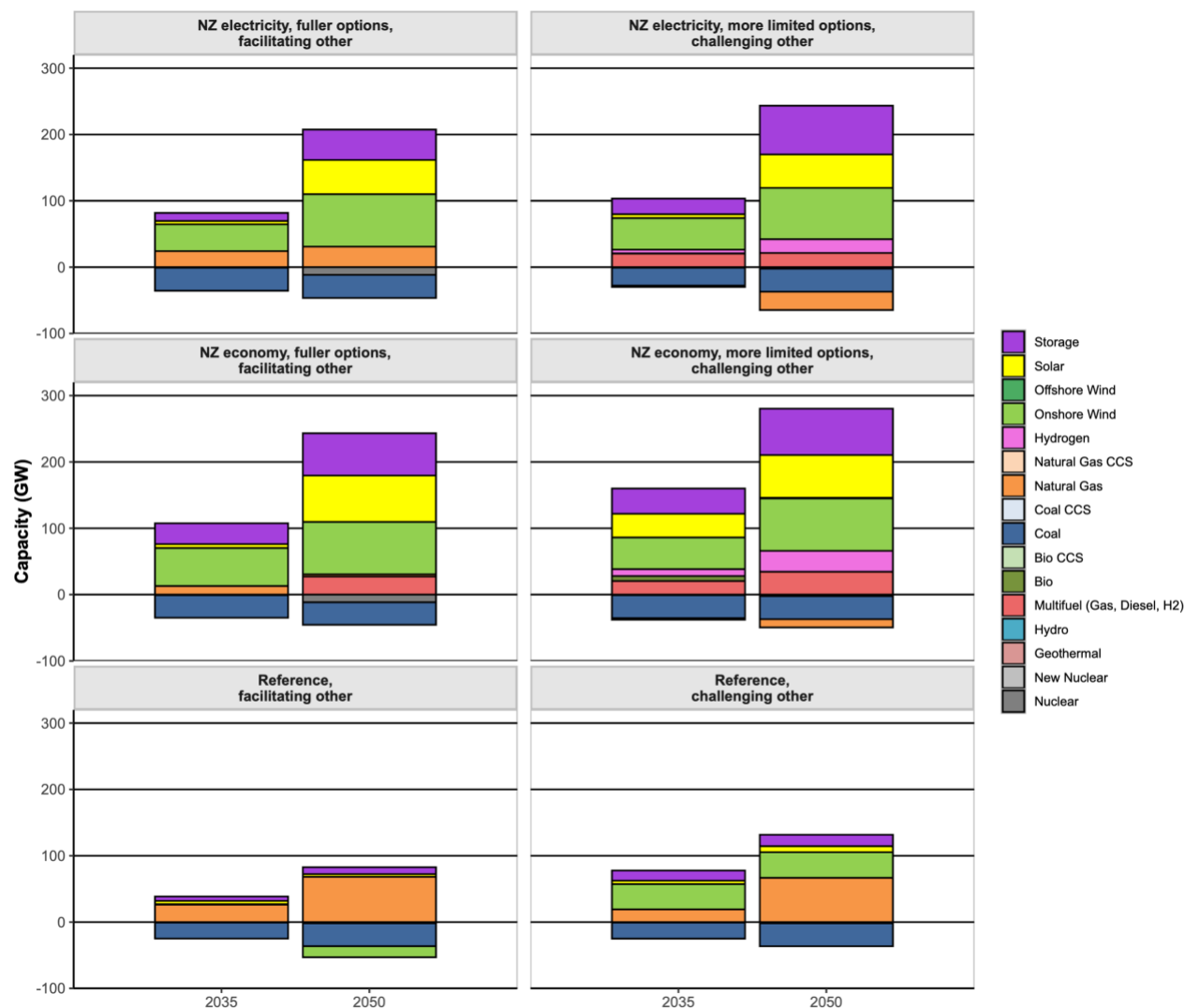


Figure BE5. Regional electricity generation capacity cumulative additions and retirements by 2035 and 2050

Source: EPRI analysis

Figure note: Cumulative capacity additions and retirements are positive and negative respectively. Illustrative results for a Midwest region of the U.S. and for the illustrative scenario design and specification. Results will vary by region of the world and scenario design and specification. Natural gas includes a mix of renewable and synthetic natural gas, and dual fuel capacity includes capacity using mixes of fossil and renewable fuels (gas and liquid).

1 The Figure BE3 and Figure BE4 results also illustrate that the roles of fossil, hydrogen, and imported power
2 resources (net power imports are the space between the load line and the top of the generation portfolio
3 in Figure BE3) are highly variable as the different conditions change the relative cost-effectiveness of these
4 options. Note, however, while the fossil generation resource (coal and gas) role is variable across the
5 alternative future conditions, fossil resources are found to be cost-effective parts of the generation and/or
6 capacity portfolios up until 2050 under all conditions. Capacity reserve requirements are met over the
7 period in different ways depending on the conditions, with some combination of coal, gas, nuclear,
8 hydrogen, dual fuel, and storage resources needed. Among other things, gas continues to serve as a cost-
9 effective capacity resource serving reserve requirements. Even in the economy-wide decarbonization
10 transitions with gas generation declining to zero, the capacity value of gas resources for reliability is
11 important. Hydrogen and dual fuel capacity resources are also helpful, especially if the decarbonization
12 options are More Limited and the other conditions are Challenging. The More Limited conditions have
13 fewer decarbonization options, in particular carbon dioxide removal (CDR) is unavailable, and the
14 Challenging conditions are more expensive and constrained in terms of new additions.

15 Figure BE3 also provides insights regarding potential future electricity demand (load) and the system size.
16 In all the scenarios we find load increasing over time. However, as mentioned, the economy-wide
17 decarbonization incentive results in the most rapid increases in load, generation, and capacity additions.
18 As noted, the economy-wide policy is creating greater demand for low-carbon electricity that is supporting
19 the additional capacity investments. Furthermore, the additional load growth from data center demand
20 in the Challenging context is further contributing to projected load growth (see the Challenging versus
21 Facilitating load growth with power sector or economy-wide decarbonization).

22 The sensitivity of the transitions to the alternative decarbonization options and other conditions depends
23 on whether there is a power sector only or economy-wide net-zero transition. For instance, the generation
24 dispatch observed in the power sector only net-zero transitions are sensitive to the Facilitating versus
25 Challenging conditions but are not very sensitive to the Fuller versus More Limited decarbonization
26 conditions. Meanwhile, the economy-wide net zero transitions are found to be sensitive to both the
27 decarbonization options and the other conditions.

28
29 Figure BE6 presents net-zero transition results for wholesale electricity power price changes by 2035 and
30 2050 relative to 2020. Electricity prices are rising in all four AT transitions, with the price increases greater
31 in 2035 (ranging from 109% to 373% in 2035 versus 21% to 50% in 2050). The greater price increases in
32 2035 indicate that there is an early adjustment challenge as the electric system and economy incur the
33 initial costs of shifting towards decarbonization. The 2035 electricity price increases are greatest in the
34 economy-wide decarbonization transitions due to the greater demand for low-carbon electricity.
35 However, the decarbonization options and other conditions affect the magnitude of the 2035 price
36 increases as well. The highest price increases with economy-wide decarbonization result from the More
37 Limited options and Challenging conditions due to the increased cost of emissions reductions.

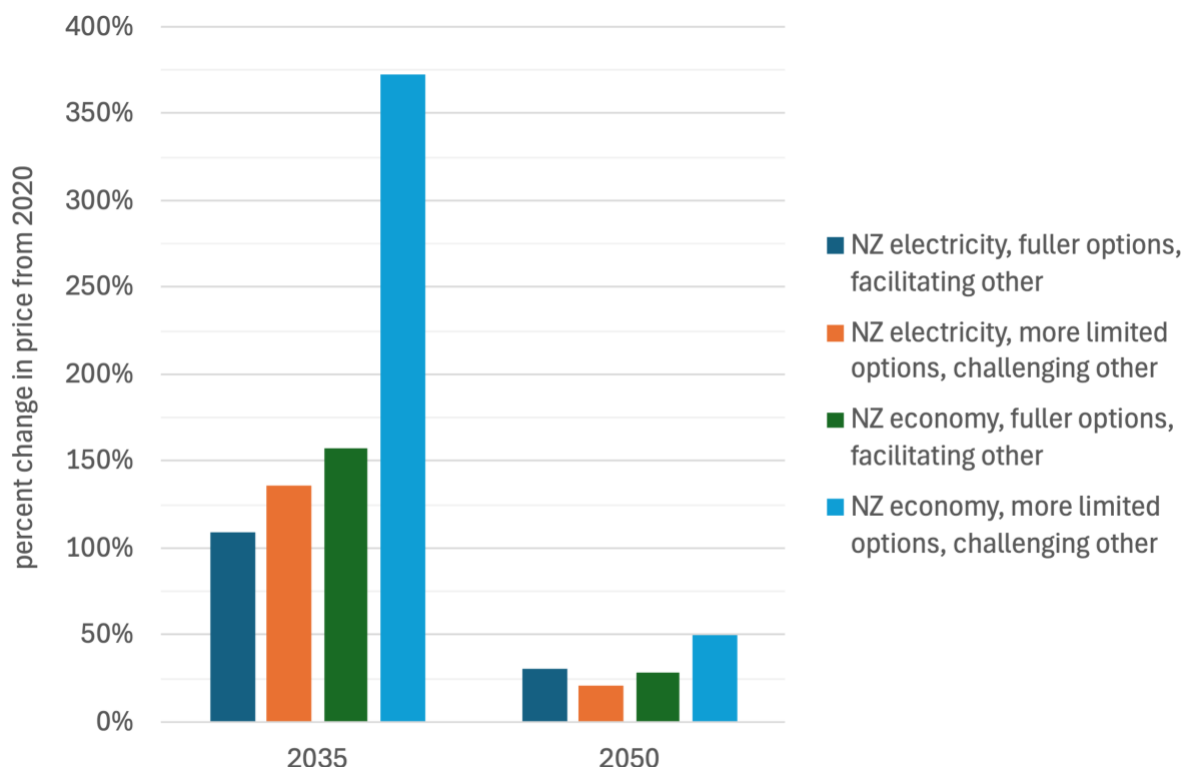


Figure BE6. Wholesale electricity price changes from 2020

Source: EPRI analysis

Figure BE7 provides net present value electricity system costs through 2050 for the net-zero scenarios, with the costs ranging from \$263 to \$376 billion. For comparison, the reference scenario costs are also shown with costs of \$230 and \$285 billion for the facilitating and challenging conditions respectively. The net-zero transitions result in an increase in projected net present value system costs with the economy-wide net-zero transition the most expensive. The majority of the costs are incurred by 2035 (Table BE8). The cost of achieving net-zero—power sector or economy-wide—is higher with the More Limited and Challenging conditions. Fuller-Facilitating is the least expensive and More Limited-Challenging the most expensive.

It is very important to keep in mind that the higher expenses with the economy-wide policy are offset by the revenues from the increased demand for low-carbon electricity. These results are not shown, but it is what is driving the cost-effective more rapid decarbonization of the power sector in the economy-wide scenarios (Figure BE2). Thus, investing in low-carbon electricity can be facilitated by policies that incentivize end-use decarbonization and increase the demand for and revenue from low-carbon electricity.

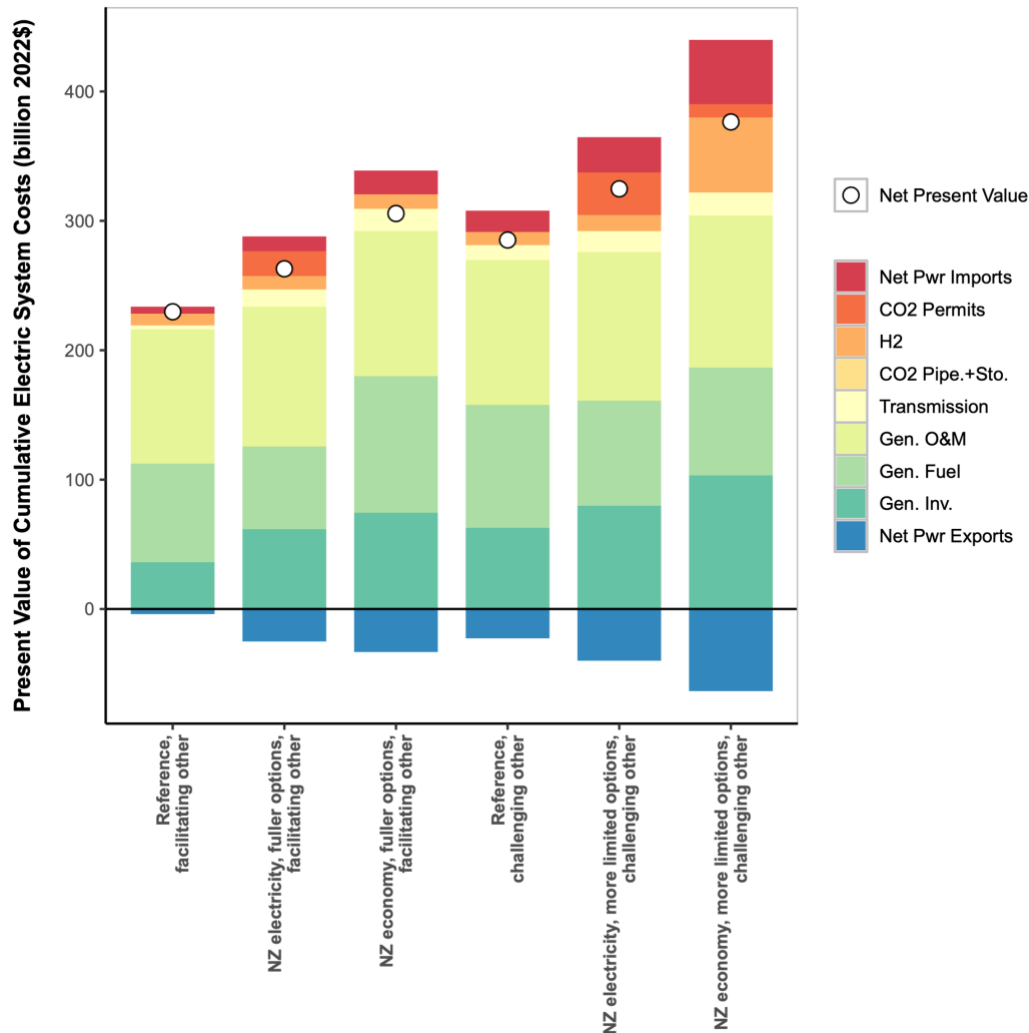


Figure BE7. Net present value electricity system costs through 2050

Source: EPRI analysis

In addition to providing important insights on potential transitions and robust strategies, the scenario analysis provides insights regarding key risks, risk factors, and risk management strategies. For instance, Figures BE3 and BE4 illustrate generation and capacity investment and operations risks, while Figures BE6 and BE7 highlight affordability risk, with the More Limited-Challenging outcome a risk a company might want to manage. The analysis also provides risk management suggestions, highlighting the risk management value of having more decarbonization options in the future, as well as pursuing Facilitating-like conditions such as lower technology costs and reducing barriers to capacity and transmission additions.

Table BE8 provides a valuable summary of results across variables and net-zero scenarios. The variables in the table can be organized according to their relevance to different company and societal priorities. In this case, the results in Table BE8 are presented in terms of variables relevant to electricity supply affordability, reliability (system stability and optionality), and sustainability. The table is particularly

valuable for summarizing uncertainty and risks. The wide ranges found illustrate that there is significant transition uncertainty relevant to affordability, reliability, and sustainability. We also see trade-offs and riskier outcomes related to affordability and reliability. For example, riskier outcomes are found in the near-term (2035) for electricity prices (potential increases of 370%), costs (possibly as much as \$300 billion), capacity additions (up to almost 200 GWs), system operations (the possibility of about 70% variable renewable resources), and load growth (possibly as much as 25%). Since the results in Table BE8 are for the region, the company would scale them to their system, utilizing the implied growth rates in prices, costs, and system changes.

We can also look within the individual scenarios and 2035 and 2050 results (Tables BE9 and BBE10 respectively) to identify the conditions associated with the riskier outcomes. Tables BE9 and BBE10 allow the company to define risk criteria that they can then apply to identify “risky” outcomes and scenarios from their perspective. For instance, if the company views a 50% electricity price increase by 2035 as a difficult trade-off and risky, then all of the AT scenarios would be considered risky given their 2035 estimated price increases of about 110% to 370%. This implies that net-zero itself will be challenging under all of the conditions from an electricity price perspective and that the options for managing this risk are limited and the company may need to consider lower emissions reductions in 2035 and possibly 2050 than associated with the net-zero pathway. Similarly, the company might define a threshold for new builds based on historical experience for new investments. Such a threshold would help the company evaluate the viability of 100 to 200 GW of new regional generation capacity by 2035 to support the decarbonization transition futures. In addition to being able to define risky outcomes, the company can use the less risky outcomes to identify enabling conditions that facilitate achieving the net-zero goal without exceeding risk thresholds. For instance, for both power and economy-wide decarbonization, Fuller decarbonization options and Facilitating conditions imply decarbonization with lower electricity price increases and fewer capacity additions (Tables BE9 and BE10).

The set of figures and tables also provide milestone and contingency insights. For instance, the results suggest the need to evaluate in a few years which future is emerging to determine if the strategy needs to be adjusted. If, for example, the decarbonization options available are turning out to look more like More Limited conditions, the company would want to evaluate increasing solar and wind investments substantially, as well as possibly slowing retirements as part of a revised cost-effective portfolio, in order to stay on track for their long-run emissions target. In general, milestones defined in terms of the More Limited/Fuller decarbonization options and the Facilitating/Challenging set of uncertainties, as well as in terms of the state of economy-wide transitions, can be used to guide company timing for when to re-evaluate their low-carbon strategy and how they might respond.

The evaluation of the ATs helps the company identify risks and the conditions that would enable the company to achieve the net-zero targets. The company then needs to evaluate the reductions it can achieve without the enabling conditions using the scenarios in Table BE5. For this example, we ran scenarios with 30%, 50%, and 80% power sector net CO₂ reduction targets by 2050. These results can be combined with the 100% (net-zero) results to construct incremental response insights regarding the implications of increasing reductions. The insights will help the company identify the best they can do while still effectively managing the trade-offs and risks. These will be the company’s QTs, and the conditions associated with them will be the qualifications.

Figures BE8 through BE13 present the kinds of results needed to help the company identify their QTs. In some charts, the AT results are also shown for comparison. Figures BE6 to BE13 illustrate how the results

1 across the range of targets can be assembled to provide incremental implication insights. Note, after
2 reviewing the initial results, we assumed this company decided to run the recommended additional
3 scenarios in Table BE5 to explore all the decarbonization option and other condition combinations, such
4 as power sector and economy-wide net-zero transitions with Fuller-Challenging conditions. Those
5 additional results are shown as well in Figures BE8 to BE13.

1 Table BE8. Regional cross-scenario result ranges for multiple variables for the AT scenarios

2 Source: EPRI analysis

3 Table note: Negative net power import results indicate net power exports from the region and that generation exceeds load in that year. For example, -23% means that in 2035 generation exceeded
4 load by 23%.

	Affordability			Stability					Optiona lity	Sustainability			
	Change in Wholesale Electricity Price	Electric Sector Costs		Total New Generation Builds	Total Generation Retirements	Net Power Imports	Variable Renewable Generation	Electric Load Growth	Dispatchable Resources	CO ₂ Emissions Reductions		CO ₂ Emissions Intensity	In-State Clean Electricity
	% Change vs 2020	\$ Billions NPV		GW from 2020	GW from 2020	% of Load	% of Total MWh	% Change vs. 2020	% of Total Capacity	% Change vs. 2020		% reduction in tCO ₂ /MWh from 2020	% of MWh
		Total	Capital							Electric	Economy		
Ranges for 2035	+109% to +373%	212 to 305	29 to 72	103 to 196	33 to 41	-23% to -3%	50% to 67%	6% to 24%	52% to 59%	78% to 100%	46% to 95%	79% to 100%	75% to 100%
Ranges for 2050	+21% to +50%	263 to 376	64 to 113	277 to 379	63 to 78	-6% to -2%	74% to 90%	30% to 79%	43% to 51%	100% to 105%	72% to 114%	100% to 104%	95% to 100%

1 Table BE9. Regional cross-scenario 2035 results for multiple variables for individual AT scenarios

2 Source: EPRI analysis

3 Table note: Negative net power import results indicate net power exports from the region and that generation exceeds load in that year. For example, -23% means that in 2035 generation exceeded
4 load by 23%. Pie chart key: wind (green), solar (yellow), gas (orange), coal (dark blue), nuclear (grey), hydrogen (pink), biopower (green), storage (purple), dual fuel (red), and hydropower (light
5 blue).

Scenario	Affordability			Stability						Optionality		Sustainability			
	Change in Wholesale Electricity Price	Electric Sector Costs		Total New Generation Builds	Total Generation Retirements	Net Power Imports	Generation Diversity	Variable Renewable Generation	Electric Load Growth	Capacity Diversity	Dispatchable Resources	CO ₂ Emissions Reductions		CO ₂ Emissions Intensity	In-State Clean Electricity
	% Change vs 2020	\$ Billions NPV		GW from 2020	GW from 2020	% of Load in 2035	Share of Generation in 2035	% of Total MWh in 2035	% Change vs 2020	Share of Fleet in 2035	% of Total Capacity in 2035	% Change 2035 vs. 2020		% reduction in tCO ₂ /MWh from 2020	% of MWh in 2035
		Total	Capital									Electric	Economy		
NZ electricity, fuller options, facilitating other	+109%	212	29	103	41	-23%		50%	6%		56%	78%	46%	79%	77%
NZ electricity, more limited options, challenging other	+136%	266	36	130	33	-4%		58%	17%		59%	78%	47%	81%	84%
NZ economy, fuller options, facilitating other	+157%	246	35	137	40	-3%		66%	14%		52%	92%	84%	93%	92%
NZ economy, more limited options, challenging other	+373%	305	72	196	41	-11%		67%	24%		54%	100%	95%	100%	100%

6

7 Table BE10. Regional cross-scenario 2050 results for multiple variables for individual AT scenarios

8 Source: EPRI analysis

9 Table note: See Table BE9 note.

Scenario	Affordability			Stability						Optionality		Sustainability			
	Change in Wholesale Electricity Price	Electric Sector Costs		Total New Generation Builds	Total Generation Retirements	Net Power Imports	Generation Diversity	Variable Renewable Generation	Electric Load Growth	Capacity Diversity	Dispatchable Resources	CO ₂ Emissions Reductions		CO ₂ Emissions Intensity	In-State Clean Electricity
	% Change vs 2020	\$ Billions NPV		GW from 2020	GW from 2020	% of Load in 2050	Share of Generation in 2050	% of Total MWh in 2050	% Change vs 2020	Share of Fleet in 2050	% of Total Capacity in 2050	% Change 2050 vs. 2020		% reduction in tCO ₂ /MWh from 2020	% of MWh in 2050
		Total	Capital									Electric	Economy		
NZ electricity, fuller options, facilitating other	+31%	263	64	277	71	-2%		90%	30%		43%	100%	72%	100%	95%
NZ electricity, more limited options, challenging other	+21%	325	76	316	78	-5%		77%	48%		47%	100%	73%	100%	100%
NZ economy, fuller options, facilitating other	+28%	306	69	319	70	-6%		88%	39%		44%	105%	102%	104%	100%
NZ economy, more limited options, challenging other	+50%	376	113	379	63	-3%		74%	79%		51%	100%	114%	100%	100%

10

Figures BE8 and BE9, for instance, show the generation and capacity portfolios over time for the different 2050 target levels. Figures BE10 to BE13 show the incremental implications for NPV electric sector costs, wholesale electricity prices, and fossil, variable renewable, and dispatchable resources. For example, Figure BE10 presents incremental net present value electric sector costs through 2035 and 2050 for the increasing levels of 2050 emissions reductions.

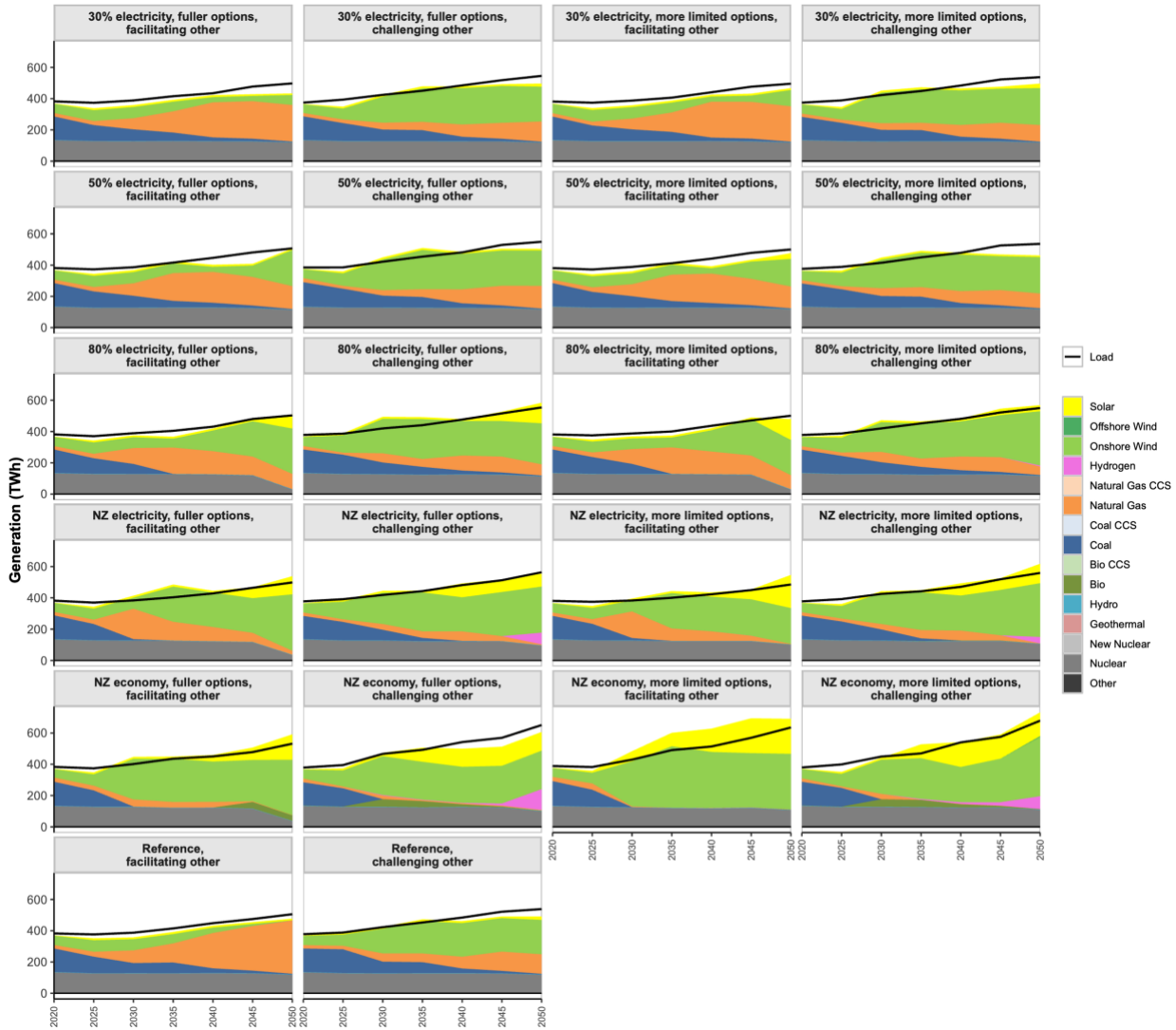
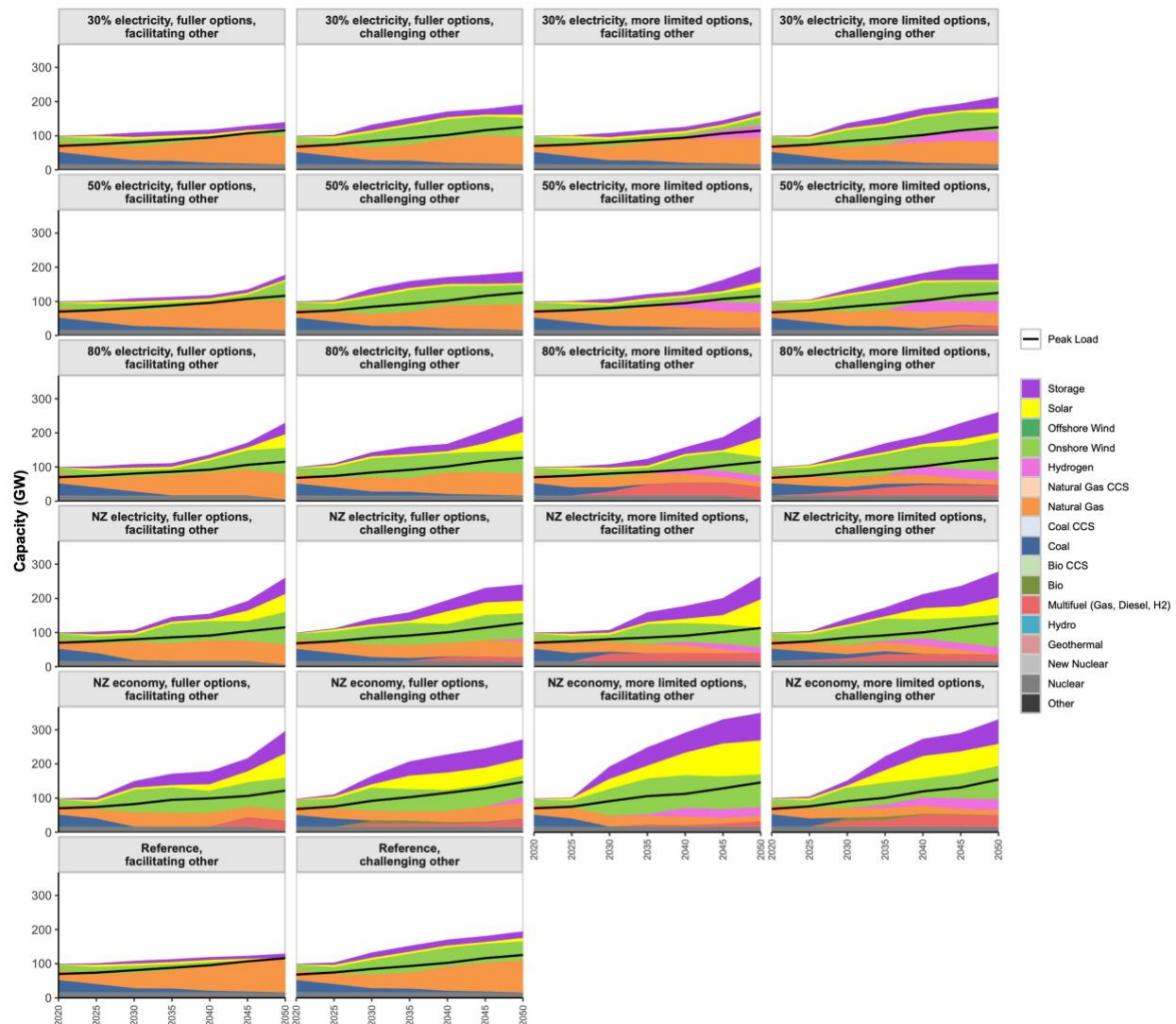


Figure BE8. Electricity generation for the increasing levels of emissions reduction ambition, Aspirational Target, and reference scenarios

Source: EPRI analysis

1



2

3 Figure BE9 Electricity generation capacity for the increasing levels of emissions reduction ambition, Aspirational
4 Target, and reference scenarios

5 Source: EPRI analysis

6

7 In Figure BE10, we see increasing discounted costs with larger reduction levels due to greater generation
8 capacity and transmission additions, O&M costs and power imports. We also see the impact of the
9 Facilitating versus Challenging conditions, where the former is resulting in substantially lower costs (20-
10 30%) in 2035 and 2050 due to the Facilitating environment's lower load growth, lower technology and
11 fuel costs, and reduced barriers for new infrastructure additions. Furthermore, we observe that the costs
12 under Fuller and More Limited conditions are similar in the power sector only decarbonization transitions.
13 Interestingly, we find that the Fuller conditions, with low-carbon power trading available, incentivize
14 additional investments driven by the opportunity for power exports. This sort of result highlights the value
15 of economy-wide modeling of the energy system and inter-regional power markets. A chart like Figure
16 BE10 also provides critical enabling condition insights. For example, for less than the costs of 50%
17 reductions with Challenging conditions, 100% reductions could be reached with Facilitating conditions.

1 Thus, efforts to reduce technology costs and lower barriers for new generation and transmission additions
2 could enable greater ambition without additional costs. Of course, the costs and benefits associated with
3 facilitating these conditions would need to be considered.

4
5 Electricity price increases are expected as well in 2035 and 2050 (Figure BE11). Electricity price increases
6 are projected for every level of emissions reduction ambition and decarbonization option and other
7 conditions. Larger price increases are projected with the Challenging conditions, and the price increases
8 are similar with Fuller and More Limited decarbonization options. Price increases in 2035 increase with
9 emissions reduction ambition and are expected to be larger than in 2050, with pursuing 30% and 50%
10 reductions resulting in about a doubling of 2035 prices (100% higher than 2020), and pursuing 80% and
11 100% reductions resulting in even larger 2035 price increases (150% higher than 2020). By 2050, there are
12 still price increases but they decline with emissions reduction level, instead of increase. This is because
13 pursuing larger emissions reductions is resulting in greater new electricity capacity additions by 2035 than
14 would have resulted from pursuing lower emissions reductions. The additional capacity additions in 2035
15 imply greater electricity supply availability by 2050 and lower price increases in 2050.

16
17 Figures BE12 and BE13 provide additional examples of incremental results and insights, showing changes
18 in incremental fossil generation capacity (coal and gas), and variable renewable energy and dispatchable
19 resource capacity by 2035 and 2050 for each of the target levels and under the alternative decarbonization
20 options and other conditions. In Figure BE12, we observe that, by 2050, coal capacity is nearly gone with
21 emissions targets of 30% or higher. By 2035, coal capacity declines significantly (at least 60%) in all
22 conditions and for all levels of reductions. The level of decline is relatively unaffected by the ambition
23 level when there are Challenging conditions. Facilitating conditions, on the other hand, allow coal to be
24 replaced more easily. Fuller option conditions also support a slightly faster decline in coal capacity. On the
25 other hand, there is the possibility of cost-effective natural gas capacity growth through 2035 and 2050
26 while decarbonizing, where increasing the level of reduction ambition could result in greater gas capacity
27 or less. By 2050, gas capacity could be significantly higher than today or eliminated. Gas growth is found
28 to be cost-effective when there are Fuller decarbonization options, with the level of growth declining with
29 ambition but potentially positive through 2050. Challenging conditions, with higher gas fuel prices, imply
30 lower levels of gas capacity, but also greater costs and price increases (Figures BE10 and BE11).

31
32 Figure BE13 provides results relevant to reliability and operations. With the Challenging decarbonization
33 conditions, there is need for significantly greater wind and solar variable renewable energy (VRE) capacity
34 growth by 2035 than with the Facilitating conditions. If the company views 250% VRE growth by 2035 as
35 an upper bound (3.5 times current VRE capacity), that would suggest that a target of no more than 30%
36 might be the best they can do in Challenging conditions. However, with Facilitating conditions, the VRE
37 capacity growth (and investment) needs are substantially lower and the company would be able to pursue
38 100% net CO₂ reductions by 2050. In 2050, we find potentially greater VRE growth than increases with
39 emissions reduction ambition in all conditions.

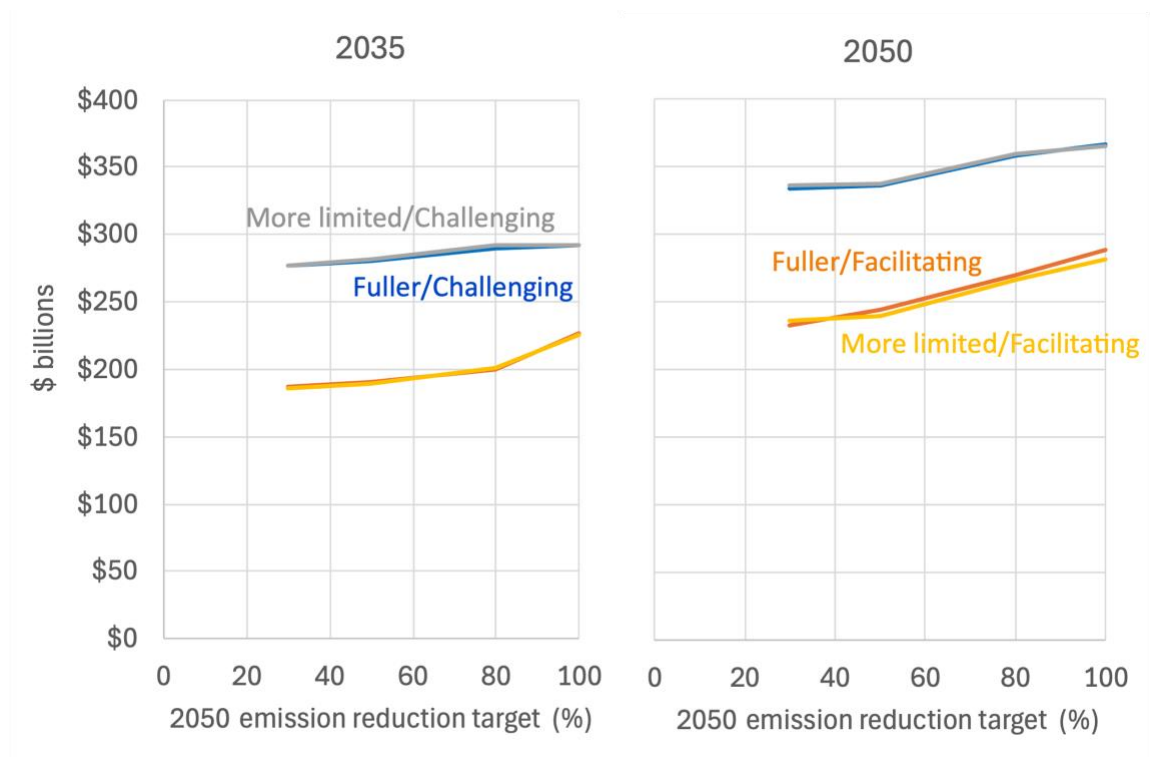


Figure BE10. Incremental discounted gross electric sector costs through 2035 and 2050 for the increasing levels of 2050 emissions reductions

Source: EPRI analysis

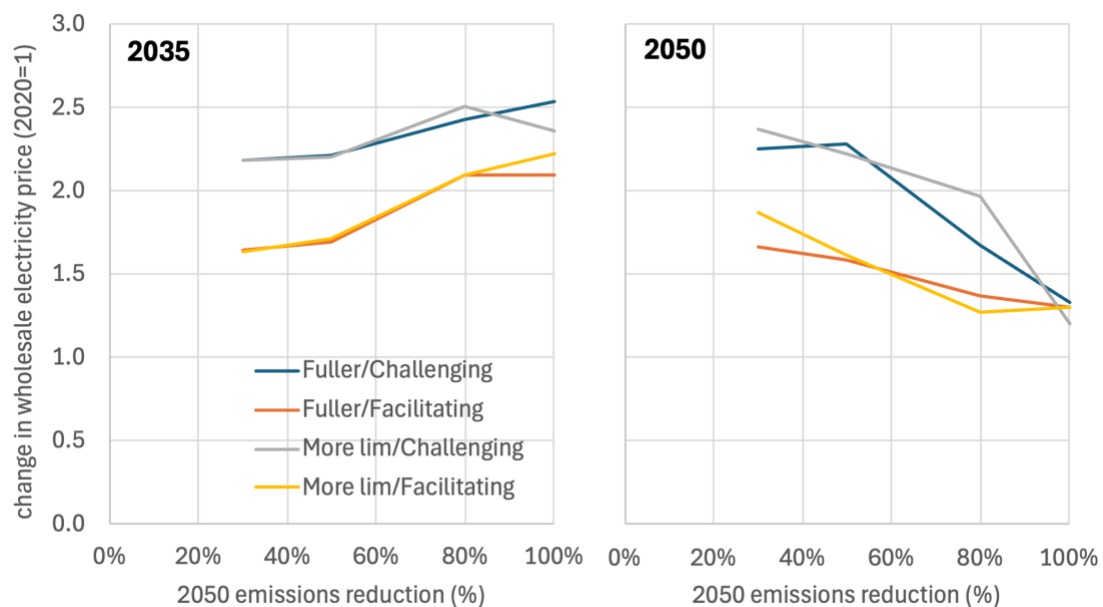
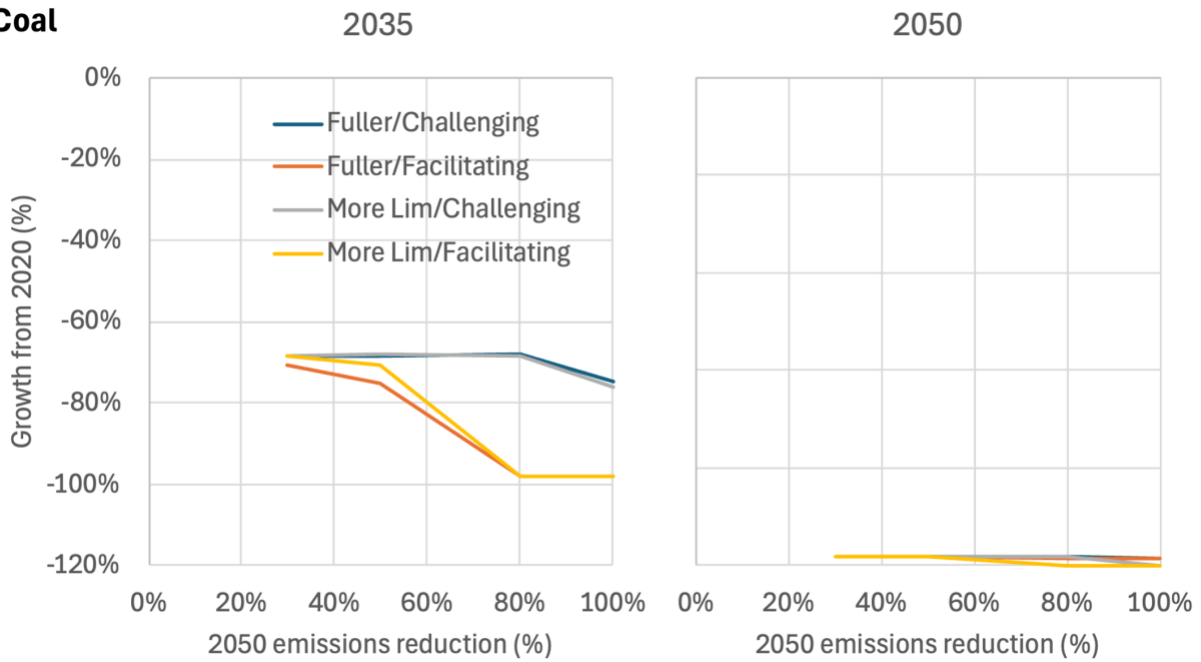


Figure BE11. Wholesale electricity price changes in 2035 and 2050 for increasing levels of emissions reduction ambition

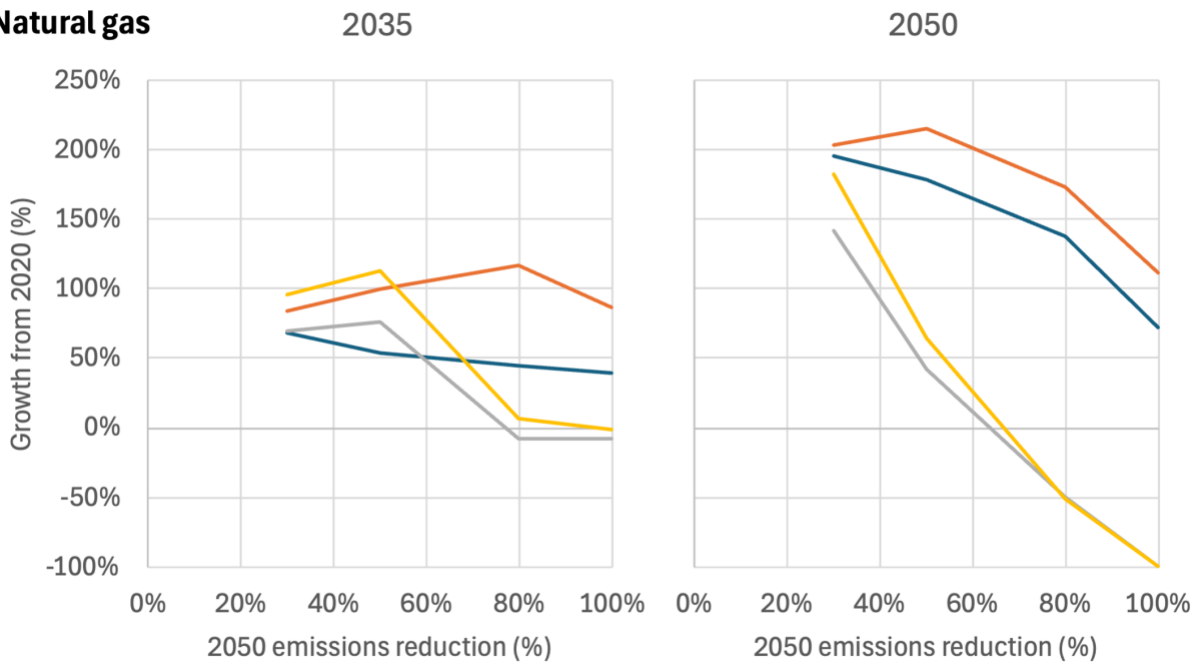
Source: EPRI analysis

1

Coal



Natural gas



2

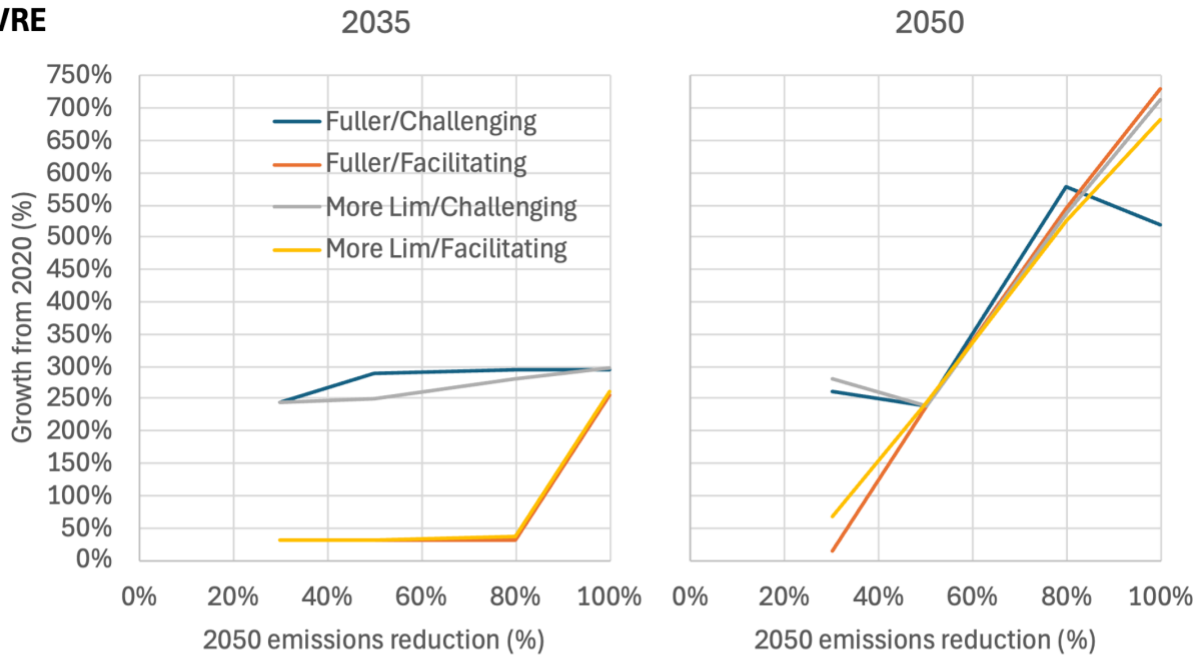
3 Figure BE12 Coal and natural gas generation capacity growth through 2035 and 2050 for increasing levels of
4 emissions reduction ambition

5 Source: EPRI analysis

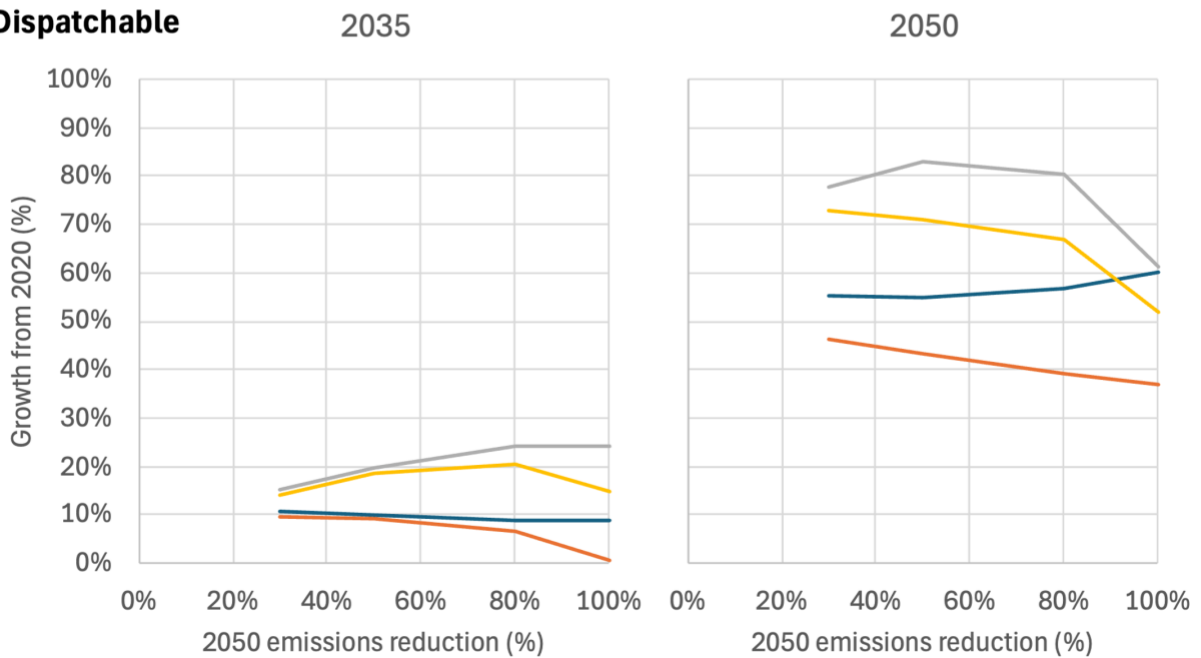
6

1

VRE



Dispatchable



2

3 Figure BE13. Variable renewable energy (VRE) and dispatchable generation resource capacity growth through 2035
4 and 2050 for increasing levels of emissions reduction ambition

5 Source: EPRI analysis. Dispatchable resources include biomass, coal, gas, geothermal, hydropower, hydrogen, nuclear, storage,
6 and mixed fuel generation capacity.

7

1 Compared to the VRE capacity growth, there is significantly less variation in the growth of dispatchable
2 resources by 2035 and 2050 across CO₂ reduction ambition levels (Figure BE13). Dispatchable resources,
3 which includes natural gas, coal, nuclear, biopower, hydro, hydrogen, storage, and dual fuels, are growing
4 under all conditions for all reduction levels. Growth in dispatchable resources is positive under all
5 conditions and ambition levels, but growth can increase or decrease with ambition depending on the
6 conditions. By 2050, growth in dispatchable resources is significantly higher than through 2035. The
7 largest growth is with More Limited-Challenging conditions, while the smallest growth is with Fuller-
8 Facilitating conditions. The More Limited options decarbonization futures are leaning harder on
9 dispatchable resources. Growth in dispatchable capacity is a robust strategy, but the exact amount is
10 uncertain. Natural gas, nuclear, and storage are key dispatchable resources in all the futures, while coal,
11 hydrogen, and dual fuels could also be important dispatchable resources depending on the future
12 conditions. Regardless of the conditions, growth in dispatchable resources should be part of the
13 company's strategy. While growing VRE is also a robust strategy, the level of growth varies substantially
14 with reduction ambition, ranging from 10% to over 700% by 2050. Note that, in 2035, the VRE growth
15 requirements could increase substantially beyond 80% reductions with the Facilitating conditions. Thus,
16 getting to net-zero by 2050, even in favorable conditions, requires over five times the growth in VRE
17 resources by 2035 than the pathway to 80% reductions.

18
19 Incremental figures like Figures BE10 to BE13 provide helpful target setting and risk management
20 information, as well as educational information for stakeholders. For instance, the Challenging conditions
21 are significantly more expensive. Even for a 30% by 2050 reduction strategy, the company may wish to
22 avoid the Challenging conditions and work with others to put in place the enabling conditions associated
23 with Facilitating. Similarly, as discussed above, Figure BE10 provides information regarding opportunities
24 and contingencies for increasing ambition. There is an opportunity for the company to pursue more
25 ambitious reductions; however, it would be contingent on whether Facilitating conditions are available in
26 the future. Similarly, a 100% target with Challenging conditions would imply additional investment costs
27 and would be information a company would want to communicate to stakeholders with an explanation
28 supported by the analysis. Furthermore, the economy-wide results from earlier highlight that end-use
29 decarbonization incentives are an important enabling condition for greater investments in low-carbon
30 generation capacity and faster electric sector and economy-wide decarbonization.

31
32 Of course, companies may want to consider additional incremental metrics related to costs,
33 infrastructure, and operations to inform their target setting and communications. They would also want
34 to consider over-time transition results like those in Figures BE8 and BE9.

35
36 Overall, the results from this step provide relevant, actionable, and transparent transition perspectives
37 that are a useful complement to company system planning. The results provide perspectives on potential
38 transitions in overall energy demand, energy markets, and economies that are relevant to the company's
39 potential system and service territory transitions and decarbonization strategies.

40 It is important to keep in mind that transition opportunities and risks can vary dramatically between
41 regions, with different transition options, different sensitivity to alternative conditions, and different risks.
42 See EPRI (2023) for examples of differences in decarbonization opportunities and risks between regions
43 within the U.S.

Outside of noting that they completed this phase, there is no documentation requirement for the company since it is an intermediate phase. SMARTargets requires documenting the final modeling results and insights in Phase 7 once iterations are complete. The company will, of course, be generating draft results and insights from this phase. However, those results are deliberative and documenting them can be confusing and misleading to audiences that are non-technical and that have not been intimately engaged in the development process.

Phase 5: Review potential transitions and target implications – based on decision-making needs

- *Phase inputs: Phase 4 preliminary transition analysis pathways and insights.*
- *Phase outputs:*
 1. *Preliminary insights regarding potential transitions, targets, and risks,*
 2. *Revisions to core scenario design, model implementation, and output reporting, and*
 3. *Additional recommended and sensitivity scenarios and specifications the company would like to evaluate.*
- *Who should be involved: Company decision-makers (e.g., directors, executives), staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.*
- *Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.*

For this phase, the company’s planning, policy, sustainability, risk management, strategy, and outreach, staff, as well as external experts, will want to engage the company’s decision-makers—directors and executives. The main objective here is to critically evaluate and discuss the preliminary results and insights to identify those they find reliable and meaningful. The additional objectives here are to identify any revisions to the core scenario design, model implementation, and output reporting they might want to make, and to identify additional scenarios and specifications that the company might like to evaluate. The last two items emerge from the company’s critique and discussion of the draft results and insights.

Given the need to identify enabling conditions, this is the time for the company to think concretely about trade-offs, risks, and risk management. The Phase 4 discussion above highlighted relevant insights from the perspective of our example company and analysis, noting specific affordability and reliability risks and enabling conditions that identify and justify the company’s QTs. Using the results from Phase 4, the company identifies challenges, trade-offs, risks, and risk management strategies. For instance:

- *Challenges and trade-offs:* The ATs are being met (or more) in all the transitions, but in each transition, we also observe challenges with affordability and reliability implications, investment implications in capacity build results, and sustainability implications with a range of emissions reductions by 2035. The set of incremental results highlight that there is no clear reduction level that is fully without consequential challenges. The Challenging conditions even make pursuing 30% reductions by 2050 difficult in terms of price increases, costs, and new capacity additions. Meanwhile, the company also found that some conditions could facilitate even greater reductions than the ATs (see risk management strategies below).
- *Risks:* The set of results highlight that all three categories of uncertainties create risk for this location, with large variation in the transitions and implications for futures achieving the ATs. Thus, uncertainty regarding the decarbonization incentive (sector versus economy-wide),

decarbonization options (Fuller versus More Limited), and other conditions (Facilitating and Challenging) are all important considerations contributing to uncertainty in the transitions, with some more difficult to manage in terms of trade-offs in prices, costs, load growth, generation and capacity resource choices, traded power, and emissions transitions.

- *Risk management strategies:* Looking across the scenarios, we can identify enabling conditions that allow for transitions with more manageable trade-offs. From careful comparison of scenarios that differ in only one category of uncertainty, we find that encouraging an economy-wide policy with end-use decarbonization incentives would facilitate faster low-carbon generation investments and emissions reductions in the electric sector. We also find that costs are lower when there are the Facilitating (versus Challenging) conditions. Challenging conditions would result in greater investment costs and could preclude achieving net-zero by 2050. The Facilitating conditions, however, would allow a company in this region to achieve net-zero (100%) for less than the cost to achieve 30% reductions by 2050 under Challenging conditions. Therefore, strategies that accelerate technology cost improvements, reduce capacity additions barriers, or lower fuel costs will be helpful. The lower costs shown in the results help justify pursuing and collaborating on strategies like these. Finally, we find that having Fuller decarbonization options (versus More Limited) has mixed effects on costs. In the power sector only decarbonization transitions the differences are modest, but in the economy-wide decarbonization transitions the differences are notable, which only highlights the importance of modeling and evaluating how the regional economy might change. Specifically, having Fuller options is found to help reduce the decarbonization challenge in the economy-wide decarbonization transitions for this region.

The key strategy for this company for enabling greater emissions reductions is therefore to pursue Facilitating conditions, policies that create demand for low-carbon electricity, and the availability of Fuller options to facilitate economy-wide decarbonization. That said, the company will also want to communicate their QTs. In this case, a transition pursuing 50% reductions by 2050 (with 17% and 33% reductions in 2030 and 2040) would be consistent with a company affordability threshold of 100% price increase by 2035. If the company cannot tolerate a 100% price increase, then they would not be able to support the 50% by 2050 reduction target. The 50% by 2050 target would also be associated with as much as \$280 billion dollars in expenditures and up to a 300% increase in VRE generation capacity by 2035. Note that these 2035 levels of expenditures and VRE capacity additions are consistent with the long-run pursuit of 100% reductions by 2050 with Facilitating conditions. As such, expenditures and VRE additions of these magnitudes would keep the company on track for 50% by 2050 reductions, as well as give the company the opportunity for greater reductions while the company works with others to put Facilitating conditions in place for achieving net-zero emissions by 2050.

This phase is also the time when the company would want to consider the likelihoods of the different futures and potential hedging strategies they might pursue. For example, if the company believes that the likelihood of an economy-wide policy is low, they might invest *less* in new low-carbon electricity capacity since the demand for clean electricity is uncertain. Furthermore, if the company believes that the Challenging conditions are more likely than Facilitating conditions, they may want to communicate the likely additional challenge for achieving the ATs and consider pursuing their QTs.

After developing preliminary results and insights, the company would want to identify whether revisions are needed to the scenario design, model implementation, and/or output reporting. In terms of identifying potential revisions to the scenario design and implementation, the group discussion should consider whether they want to tweak anything. This could include revising what is included in the Fuller and More Limited decarbonization options sets, making Facilitating/Challenging more extreme to further differentiate them, or simply adjusting a specification such as the annual additions constraints for new generating capacity or transmission. This conversation should also include discussion of whether to run additional scenarios—the recommended additional scenarios or custom sensitivity scenarios. As noted above, we assumed the company’s assessment of their preliminary results led them to decide to run the recommended additional scenarios in Table BE5. See the Phase 6 discussion for sensitivity scenario examples.

The company discussion on potential sensitivity scenarios should look for meaningful adjustments to one or two assumptions. For example, based on the results above, this company might want to consider running More Limited with CDR scenarios (power sector and economy-wide net-zero) that add CDR to the More Limited decarbonization options set. They might also want to consider running the Challenging scenarios with economic, instead of constrained, capacity additions. This scenario would run the Challenging conditions but with the annual capacity addition constraint removed.

Like Phase 4, outside of noting that they completed this step, there is no documentation requirement for the company since it is an intermediate phase. SMARTargets requires documenting the final modeling results and insights in Phase 7 once iterations are complete.

Phase 6: Revise and iterate as needed – revising scenario design, implementation, and model results

- *Phase inputs:*

1. *Phase 5 revisions to core scenario design, model implementation, and output reporting, and*
2. *Phase 5 sensitivity scenarios and specifications the company would like to evaluate.*

- *Phase outputs:*

1. *Revised insights regarding potential transitions, targets, and risks, and*
2. *As needed, additional revisions to scenario design, model implementation, and transition pathways.*

- *Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.*

- *Stakeholder engagement: This is a good time to seek external stakeholder feedback.*

- *Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.*

For this phase, the company’s planning, policy, sustainability, risk management, strategy, and outreach, staff, as well as external experts, will work together to revise the insights regarding potential transitions, targets, and risks; and, as needed, implement any needed revisions to the scenario design, model implementation, and transition pathways.

Phase 6 is also a good time for external stakeholder feedback. After internal iterations, the company will have a final draft scenario design, results, insights, and strategies to share and discuss. This gives the company an opportunity for education and dialogue, as well as to solicit feedback on their potential transitions, challenges, uncertainties, risks, enabling conditions, risk management, and collaboration opportunities.

For this phase, the company continues to iterate on the scenario design, specification, results, and insights until they have agreement with their decision-makers. Like Phase 5, outside of noting that they completed this phase, there is no documentation requirement for the company since it is an intermediate phase. SMARTargets requires documenting the final modeling results and insights in Phase 7 once iterations are complete.

Phase 7: Communicate results – targets, transitions, risks, enabling conditions, risk management

- Phase inputs:

1. Phase 6 final scenario design (core and additional scenarios), model implementation, and transition pathways, and
2. Phase 6 final insights regarding potential transitions, targets, risks, enabling conditions, and risk management.

- Phase outputs:

1. Documented scenario analysis, outputs, and insights,
2. Aspirational Targets (ATs), strategies, and risk management, and
3. Qualified Targets and their qualifying conditions (QTs) and strategies.

- Who should be involved: The company's decision-makers (e.g., directors, executives), staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.

- Documentation: SMARTargets Reporting Template summarizing the following:

1. The company's ATs and QTs with corresponding conditions,
2. The company's enabling conditions, strategy, risks, and risk management,
3. The company's transition risk analysis (modeling, scenario design and specification, potential transitions, insights), and
4. The implementation process.

This phase is the critical communications of all the company has done for the Step 4 analysis. For this phase, the company will want to work with their decision-makers and company planning, policy, sustainability, risk management, strategy, and outreach teams. They will also want to engage their external experts to help with documenting the methodology and effectively, rigorously, and defensibly communicating the results. The experts can also help the company communicate the relevant science to educate readers and ground the methods.

At the end of Phase 7, the company will use the SMARTargets Reporting Template to finalize the documentation for their Step 4 transition risk analysis (Phases 1 through 7). This includes the summary tables of key output indicators, as well as graphics to help communicate the company's modeling results and insights. Additionally, the company will report the identified enabling conditions for ATs, QTs and corresponding conditions, and the risks and opportunities identified. Finally, the company will indicate their risk management strategies along with their milestones and contingency plans.

The company's strategy will consist of more than targets. It will also include transition plans as well as strategies for pursuing enabling conditions and managing risks, where the latter might entail research and development plans, collaboration with customers or other sectors, and policy dialogue. Step 4 has a minimum set of required outputs (Table 20 in the methodology document). Additional variables may be added based on company need (e.g., air pollutant emissions, differentiated affordability indicators).

Step 5. Strategy and qualified target alignment with international goals

Step 5 Outputs: International goal alignment assessments of qualified targets and strategies.

In this step, the company will evaluate *qualitative* alignment of their transition strategy with the international goals, as well as *quantitative* alignment of their QTs.

Assessing qualitative alignment of the transition strategy

The company will assess two types of qualitative alignment of their strategy with international goals: (1) alignment with the types of transitions robustly observed in global emissions pathways consistent with the Paris Agreement temperature goals, and (2) alignment with the provisions in the Paris Agreement associated with achieving the temperature goals.

As discussed in the methodology document, the following are robust types of transitions found in all global 1.5°C and 2°C emissions pathways. The following are changes found consistently in well-below 2°C pathways regardless of the model and assumptions:

- Increasing low-carbon technology deployments,
- Increasing reliance on electricity,
- Transitions away from fossil fuels but continued use,
- Use of carbon dioxide removal,
- Improvements in energy conservation and efficiency,
- Differences in regional low-carbon transitions, and
- For any climate goal, substantial uncertainty in the levels, rates of change, and composition (e.g., technologies, energy, activity) of the transition of the global economy.

The Step 4-Phase 4 analysis results above do not cover all these perspectives. However, what they do provide is qualitatively aligned in that they exhibit increasing reliance on electricity, decreasing reliance on fossil fuels, increasing deployment of low-carbon technologies, and use of carbon dioxide removal and energy conservation and efficiency (last two not shown). They also exhibit significant uncertainty in the transitions and, by design, recognize the unique low-carbon transition opportunities.

Furthermore, the transitions and insights align with Paris Agreement's provisions recognizing differences in national decarbonization opportunities, multiple societal priorities, transparency, and the value of innovation and cooperation (in this case across sectors via the economy-wide scenarios).

Assessing alignment of the Qualified Targets

The company will also assess quantitative alignment of their QTs through comparison to the relevant global emissions pathway ranges consistent with the Paris Agreement objective of limiting global average temperature to "well-below" 2°C. Table BE11 shows this comparison from which this utility would

conclude that their QTs are quantitatively Paris Agreement aligned. Based on the Step 4 transition risk analysis, we assume this utility identified two sets of QTs:

1. 50% reductions by 2050 (with 17% and 33% reductions in 2030 and 2040)
2. 89% reductions by 2035 (with 93% and 100% reductions in 2040 and 2050)

The conditions associated with the first set of QTs include the following: electric sector only decarbonization transition and Challenging other conditions. The conditions associated with the second set of QTs include the following: economy-wide decarbonization transition, Fuller options, and Facilitating other conditions. The sets of QTs were identified by considering the transition implications for affordability (prices, costs, investments), new infrastructure requirements, and operational reliability, as well as the likelihood of future conditions.

As discussed in the methodology document, the high-level insight from the Table BE11 comparison is that QTs within the ranges are aligned with global futures consistent with limiting warming to well-below 2°C. Furthermore, if all companies have QTs within the range, the sum will also be aligned with well-below 2°C. However, it is critical to keep in mind that this comparison is not conclusive because the global pathways do not capture the transition opportunities and challenges for individual companies, or differences across companies. In addition, the global pathway ranges do not reflect all the sub-global and local transitions found to be aligned with a global temperature. Thus, QTs for some companies may not fall within the global pathway ranges due to their transition challenges. The QTs should not be judged negatively based on this comparison. This outcome is simply an indication of the company’s challenges. The QTs should be evaluated in terms of their challenges and the strategies for pursuing them and enabling conditions for additional ambition. The QTs represent the highest possible ambition for a company under different conditions while balancing trade-offs and risks that the company would be transparently identifying and communicating. Specifically, the company would communicate what conditions are determining their QTs, as well as how additional reductions could be possible under other conditions.

Table BE11. Qualified Target Paris Agreement alignment assessment

Qualified Target set	Key qualifying conditions	GHG		Qualified Target 2050	Well-below 2°C ranges	Within range
1	Electric sector only decarbonization transition and Challenging other conditions	Net CO ₂	2030	-17%	10% to -100%	Yes
			2040	-33%	-24% to -121%	Yes
			2050	-50%	-43% to -126%	Yes
2	Economy-wide decarbonization transition, Fuller options, and Facilitating other conditions	Net CO ₂	2030	-89%	10% to -100%	Yes
			2040	-93%	-24% to -121%	Yes
			2050	-100%	-43% to -126%	Yes

In addition to the above documentation, the company might also want to communicate quantitative Paris Agreement alignment visually. A graphic like Figure BE14 can be created and is a grounded, effective

means to quantitatively communicating alignment of the company targets and transition risk analysis pathways with the Paris Agreement temperature goals.

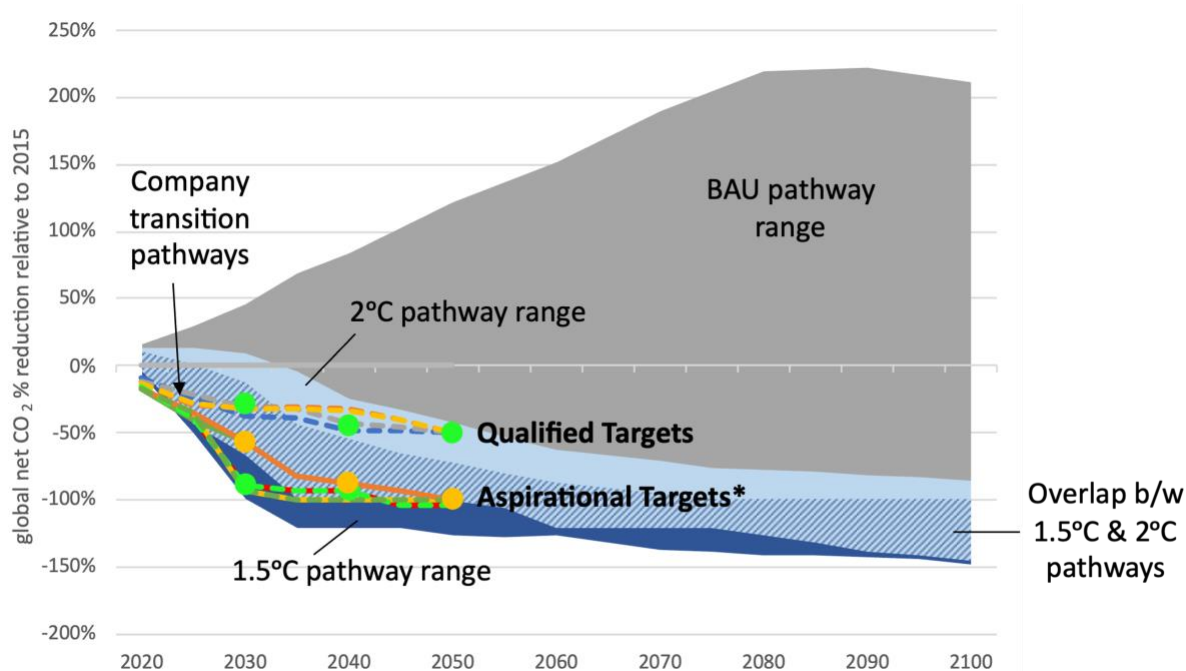


Figure BE14. Alignment of illustrative company Aspirational and Qualified net CO₂ Targets and transition risk pathways with the global emissions pathways consistent with the Paris Agreement temperature goals

Source: EPRI.

Figure notes: Aspirational Targets denoted with yellow dots with solid line transition pathways. Qualified Targets denoted with green dots with dashed line transition pathways. Figure developed from EPRI (forthcoming) analysis of the IPCC's Sixth Assessment Report, IEA Net Zero by 2050, and other recent global emissions pathways, and the EPRI illustrative US-REGEN analysis completed for this example. See EPRI (forthcoming) and EPRI (2020 and 2018) for detailed assessments of recent and previous global emissions pathway modeling and results, including discussion of global pathway limitations and the importance of using full ranges due to the nature of the IPCC data.

* Enabling conditions may be needed to achieve the Aspirational Targets. See the company transition risk analysis and narrative that identifies the enabling conditions and Qualified Targets and their conditions.

Step 6. Documentation and communication

Step 6 Output: SMARTargets documentation.

In this step, the utility will document and communicate their SMARTargets implementation using the SMARTargets Reporting Template. This includes documenting implementation choices with justification, transition analysis insights, targets, strategy, and milestones. Through the template, the following information will be assembled:

- General company information and stakeholder engagement,
- GHG Inventories and base year,
- Practical issues and climate target groupings,
- Company transition risk analysis of opportunities and risks,
- Alignment assessment,

- Documentation and communication of targets, strategies and indicators, and
- Implementation and monitoring.

The set of information represents a clear, comprehensive, and transparent package of information about the process and the outcomes. Overall, in applying the methodology, the utility will produce the following standardized and comparable results that reflect their implementation and climate strategy:

- a. Paris Agreement-aligned targets and enabling conditions, including Aspirational Targets (AT) and Qualified Targets (QT) and their associated conditions,
- b. Insights into potential low-carbon transitions,
- c. Assessment of risks, risk management strategies, and overall transition strategy, and
- d. Documentation of methodology implementation, including:
 - GHG inventory by required emissions category,
 - Responses to practical considerations and target-setting decisions for each category,
 - Transition risk analysis components:
 - Modeling approach
 - Reference conditions and key uncertainties
 - Core scenario definitions and specifications
 - Criteria for identifying risks and enabling conditions

In addition, the company is encouraged to holistically communicate their strategy. This goes beyond emissions targets and includes leadership strategies to help create the enabling conditions for achieving greater emissions reductions and economy-wide decarbonization, such as research and development (R&D), educational outreach (stakeholder and policy), and collaboration and coordination with customers and supply chain partners. For this illustrative utility, the analysis has identified that, among other things, strategies related to the following would be helpful and worth considering: encouraging end-use decarbonization incentives that create a market for low-carbon electricity, having access to carbon dioxide removal technologies, accelerating technology cost improvements, and reducing capacity additions barriers.

In addition, the company might consider communicating on the SMARTargets Methodology itself, including its scientific foundations. This can involve referencing the publicly available methodology, the SMARTargets Scientific Foundations, and other materials and emphasizing how the approach is science-based and aligned with the Paris Agreement (see Justification for the Methodology section).

Step 7. Validation and Verification

Step 7 Outputs: Validated SMARTargets and verified progress.

In this step, the utility will validate their SMARTargets and verify progress. After completing the SMARTargets Reporting Template in Step 6, the utility will be able to initiate validation activities. Validation assesses whether the methodology has been properly implemented and whether the target and strategy—by nature forward-looking statements—are supported by sound assumptions, data, and methods. The primary input for validation is the SMARTargets Reporting Template.

The utility should begin with internal validation, leveraging internal audit processes aligned with recognized standards. This step ensures the methodology has been correctly applied and that the resulting targets and strategies are scientifically grounded and aligned with the Paris Agreement. Internal

validation also builds confidence by thoroughly documenting the rationale and process behind the targets—information that is essential for both third-party validation and external communications.

Internal validation is all that is possible in the near-term. Accredited, independent third-party validation services for corporate GHG targets do not currently exist. Third-party validation is recommended once it becomes available. It provides an independent, authoritative assessment of conformity with the SMARTargets Methodology and validation criteria.

Following validation, the utility will communicate the results with the public, including regulators, investors, and other interested stakeholders.

In addition to validating, the utility is required to verify progress periodically. The utility will evaluate actual emissions reductions against its targets using the most recent GHG emissions inventory. The same third-party provider that verifies the GHG inventory could also perform this progress verification, thereby ensuring consistency and credibility with reporting. This verification relies on GHG inventories, which are based on observable data and are therefore subject to assurance-level assessments.

Step 8. Monitoring and adjusting

Step 8 Outputs: Periodic milestone assessment and, as needed, strategy adjustment and/or SMARTargets refresh.

Under this step, the company will annually monitor their milestones and adjust their strategy as needed. The utility will need to monitor conditions with respect to their milestones to determine if strategy adjustments are needed and/or if updated SMARTargets analysis, targets, and strategies are needed.

The transition risk analysis (Step 4) provides milestone and contingency insights as well as insights regarding transition opportunities and risks. The company should articulate meaningful and observable milestones, and potential responses, based on their analysis, with the milestones clearly communicated in the Reporting Template. For instance, the Step 4 results above suggest the need to evaluate which future is emerging. If, for example, the decarbonization options available are turning out to look like the More Limited set, instead of the Fuller set, in order to stay on track with their long-run emissions targets, the utility would want to consider alternative strategies for gas, solar, wind, storage, and hydrogen, as well as possibly slowing retirements if annual additions are likely to be constrained. Furthermore, those strategies will depend on whether sector or economy-wide decarbonization incentives are emerging, which is another milestone the utility can readily monitor. If economy-wide decarbonization incentives are developing that increase low-carbon electricity demand then the utility should consider accelerating clean energy investments (and emissions reductions).

Illustrative results for T&D utility emissions targets

This example illustrates the derivation of SMARTargets for transmission and distribution (T&D) utility emissions for a hypothetical company that provides T&D services supporting the delivery of electricity. T&D infrastructure is critical to the provision of electricity to customers, including supporting the potential increased use of electricity to help decarbonize economies.

The primary categories of GHG emissions for this utility are the following:

1. CO₂ emissions from electricity that is sold to end users (scope 3),²
2. CO₂ emissions from T&D line losses in the process of transmitting electricity to points of distribution and in the final distribution of that electricity to customers (scope 1, 2, or 3),³ and
3. SF₆ (sulfur hexafluoride) fugitive emissions from T&D equipment (scope 1),⁴

Uncertainty regarding electricity supply and demand creates uncertainty for T&D emissions, targets, and strategies, with uncertainty in total power flows, T&D infrastructure needs, and the mix of electricity generation resources (low-emitting and emitting). T&D utilities need to evaluate these uncertainties to identify opportunities and risks and set actionable targets and practical strategies.

The regulatory environment is also relevant. In some jurisdictions, T&D utilities have the ability to influence generation decarbonization through green procurement strategies, while in other jurisdictions, utilities may not have control or influence over the generation resources. For instance, some T&D utilities may be subject to regulations requiring least-cost electricity procurement that constrains their ability to recover potential premiums for low-emitting resources.

In this example, we consider an illustrative T&D utility in a U.S. Midwestern region. The company sits within the region and is interested in understanding how the regional electric power market and economy might evolve with decarbonization by 2050 and what might be the implications and risks. Using US-REGEN, we can constrain emissions and evaluate alternative potential low-carbon transitions for the regional electric power market, the three categories of GHG emissions, and GHG abatement opportunities.

Below, we describe how this T&D utility would apply each step of the SMARTargets Methodology.

Step 1: GHG inventories and base year

Step 1 Outputs: Verified GHG inventory and emissions reductions base year.

The first step is for the company to assemble their GHG inventory and select a base year. The company will need GHG emissions accounts for each of the categories of emissions relevant to their business. The

² These emissions are classified as scope 3 emissions for companies that do not own generating assets according to the GHG Protocol.

³ Transmission losses are classified in the GHG Protocol in different scopes depending on company structure. For vertically integrated utilities, T&D transmission losses will be already considered in stationary combustion of electricity generation scope 1. For “wires-only” T&D utilities, transmission losses will be considered scope 2. And for independent power producers, T&D transmission losses that occurred in a separate “wires only company” are scope 3.

⁴ According to the GHG Protocol, SF₆ fugitive emissions are classified as scope 1 emissions directly related to the operation of T&D assets.

company will also need to decide on their emissions reduction base year and apply it consistently. Note that the company will need to have the inventories verified.

For this example, Table BTD1 summarizes the emissions for our illustrative utility. The primary source of emissions is CO₂, emissions from purchased power to serve load. The utility could have other emission sources but, for this example, we assume they represent only a small fraction of the overall inventory and are immaterial. Table BTD1 presents the inventories for the utility's base year and their most recent inventory.

The GHG emissions trends for each category are shown in Figure BTD1. T&D related CO₂ emissions have been declining over the last decade. An analysis of drivers, reveals that this is due primarily to reductions in fossil fuel-based electricity generation and reductions of energy losses on the T&D network. SF₆ emissions have declined significantly since 1990, primarily due to enhanced controls targeting fugitive emissions. However, since 2015, SF₆ emissions have increased due to an expanding system and additional T&D infrastructure.

Given the information available, we assume the utility decides to select 2015 as its base year. This decision is based on considering the accuracy of their inventories, the inventory years verified, and choosing a year that facilitates communications regarding the utility's emissions trends. Given the relevance of emissions from electricity sold to customers, the utility notes that accounting improvements are needed to better reflect CO₂ emissions from this category (scope 3).

Table BTD1. GHG Inventory for key categories in T&D utility illustrative example

Source: EPRI with data from US-REGEN, DOE (2024), EPA (2024), and an illustrative T&D utility inventory.

Key emissions categories	2015 (base year)	2021 (most recent)
	MtonCO ₂ e	
CO ₂ from electricity sold to end users	4.5	3.4
CO ₂ from T&D line losses	9.5	6.9
SF ₆ fugitive emissions from T&D equipment	42.1	48.4

Step 2. Practical issues and climate target groupings

Step 2 Outputs: Decisions on practical issues, including emissions categories covered (by regulation or company targets), the categories for which targets are being set, and how these categories are grouped for target evaluation.

For this step, our illustrative T&D utility works through the company target setting practical issues, as well as identifies their target groupings. Table BTD2 presents example responses to the set of practical issues questions for all three emissions categories, and below we discuss the implications. This step helps the company assess practical considerations that may influence their ability to set and achieve targets. The company's responses also inform their evaluation of targets (Step 4). Note that, in our example, we

assume the company owns and operates T&D equipment only. It is a “wires-only” utility. They do not own generating assets.

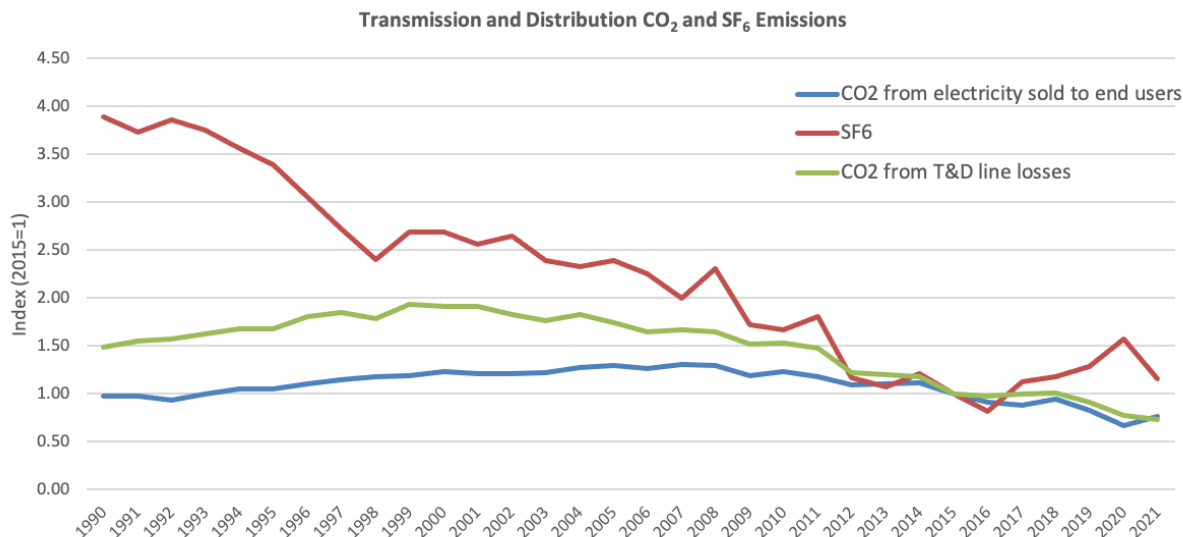


Figure BTD1. Emissions trends for key emissions categories in T&D illustrative example

Based on the responses in Table BTD2 above, this company should consider evaluating and pursuing targets for all three categories. The local jurisdiction has Paris Agreement aligned regulations for electricity generation emissions. Thus, the utility should consider whether or not to set targets for CO₂ from electricity sold to end-users since the emissions are already covered and managed to a Paris Agreement aligned level. It is possible that another T&D utility would have different answers. For instance, another company could be in a state with regulation mandating a phase out of SF₆ in gas-insulated equipment. In that circumstance, setting a target for SF₆ could be unnecessary or even complicate/conflict with compliance. The company would want to evaluate its context and decide whether target setting is the best strategy to manage these emissions.

Recall that, for each emissions category, the company decides whether to:

1. Set a target (using the subsequent SMARTargets steps),
2. Not set a target because the emissions are already covered by a Paris Agreement aligned policy or another company’s Paris Agreement aligned targets,
3. Not set a target with justification based on practical considerations that currently preclude target setting, or
4. Not set a target because the category is not relevant to their business.

For the sake of this illustration, we assume the T&D utility decides to pursue targets for all three categories. The targets will have risk since the company does not control the size of the power market or the generation mix. The company has some control over the procurement process and could influence the market by demanding low-carbon electricity. The bottom line is that the utility should be sure to evaluate and communicate the implications of power market uncertainty.

In this step, the company also needs to decide on its target groupings. For this example, we assume the company pursues separate targets for each of the three emissions categories. The company has decided

1 to have separate CO₂ and SF₆ targets due to specific reporting requirements for SF₆, as well as the
 2 modeling requirements and options for evaluating abatement of each gas and category. The company's
 3 overall target setting and target grouping decisions are documented in Table BTD3

4 Table BTD2. Practical issues responses for the illustrative T&D utility

Company target setting practical considerations question	Response for CO ₂ from electricity sold to end-users (scope 3 Category 3 Fuel- and energy-related activities not includes in scopes 1 and 2)	Response for CO ₂ from T&D line losses (scope 1, 2, or 3)	Response for fugitive SF ₆ from T&D equipment (scope 1 Direct emissions from fugitive sources)
Is the emissions category adequately estimated and reported?	Yes, emissions reported using location-based and market-based methods	Yes, the emissions are estimated and reported using the location-based method	Yes, emissions are estimated in the inventory since 2000 with improvements over time. Among other things, the company has implemented a monitoring system that has improved the inventory and management ability. However, emissions from the distribution system are estimated using the IPCC's Tier I emissions factors, which are known to be imprecise.
Are the emissions material to the company's overall GHG inventory? (e.g., above 5% of total emissions or a threshold defined by the company)	Yes, the emissions from this source category are greater than 5% of emissions	Yes, the emissions from this source category are greater than 5% of emissions	Yes, the emissions from this source category are greater than 5% of emissions
Are the category's emissions regulated by a Paris Agreement aligned policy?	Yes, the utility's local jurisdiction has Pairs Aligned CO ₂ targets (intermediate and net zero by 2050)	No, the emissions from this source category are not currently regulated	No, the emissions from this source category are not currently regulated
Does another company in the value chain already set Paris Agreement-aligned targets for this source? (applicable only to indirect emission sources)	No, although some utilities in the area are working with the SMARTargets framework to implement targets and design strategies	No, the source does not currently have a Paris Agreement-aligned target	n/a, these are direct emissions
Does the company have control or influence over the emissions?	Limited, the utility can influence the purchase of electricity but it depends on the availability and timeliness of clean energy resources	No, the utility does not control the size of the electricity market, and has only limited control over the energy mix	No, the utility does not control the size of the electricity market

5

Table BTD3. Emissions category targets

Table note: Emissions categories are those from Table B1. * Emissions not relevant to business or not material to inventory.

Emissions category	GHG total (MtCO ₂ e or NA if not relevant to business)	Currently covered				To be covered by <u>future</u> Company SMARTargets (MtCO ₂ e)	Not Covered (MtCO ₂ e)	Justification (and, as relevant, plans for not covered emissions and future targets)
		By Our Current Company SMARTargets (MtCO ₂ e)	SMARTarget type (indicate if target for category, GHG, or CO ₂ e)	By Paris Agreement Aligned Regulation (MtCO ₂ e)	By Another Company's Paris Agreement Aligned Targets (MtCO ₂ e)			
Scope 1. Direct Emissions from Stationary Combustion	0.0 (< 0.1)							Not material*
Scope 1. Direct Emissions from Mobile Combustion	0.2							Not material*
Scope 1. Direct Emissions from Process Sources	n/a							n/a
Scope 1. Direct Emissions from Fugitive Sources	3.4	3.4	SF ₆					Fugitive SF ₆ emissions are material
Scope 2. Indirect Emissions from Purchased/Acquired Electricity	7.1	6.9	CO ₂					The target covers CO ₂ emissions from T&D losses which are material, other scope 2 emissions (e.g., electricity purchases for buildings) are not material
Scope 2. Indirect Emissions from Purchased/Acquired Steam	n/a							n/a
Scope 2. Indirect Emissions from Purchased/Acquired Heating	n/a							n/a
Scope 2. Indirect Emissions from Purchased/Acquired Cooling	n/a							n/a
Scope 3. Fuel- and energy-related activities (not included in scope 1 or 2)	48.4	48.4	CO ₂					CO ₂ emissions from purchased power for resale are material
Scope 3. Use of sold products	n/a							Not material*

Step 3. Aspirational targets aligned with international goals

Step 3 Outputs: Aspirational targets that will be evaluated in the Step 4 transition risk analysis.

For this step, the utility will select generic Aspirational Targets (ATs) aligned with the international goals for their SF₆ and net CO₂ targets. The utility identifies intermediate and 2050 ATs using Table BTD4, which shows the SF₆ and net CO₂ ATs from Table 6 of the methodology document. The utility must select a 2030 or 2035 intermediate AT, as well as a 2050 AT. They are also welcome to select additional pre-2050 intermediate targets using the table. For this example, we assume the utility chooses to select 2030 and 2040 intermediate ATs and therefore their set of SF₆ ATs are -37%, -41%, and -47% from 2015 for 2030, 2040, and 2050 respectively; and, their set of net CO₂ ATs are -56%, -88%, and net-zero (-100%) from 2015 for 2030, 2040, and 2050 respectively.

Table BTD4 Generic Aspirational Targets (% reduction from 2015)

	SF ₆	Net CO ₂
2030	-52%	-56%
2035	-52%	-82%
2040	-52%	-88%
2045	-52%	-94%
2050	-52%	-100%

Step 4. Company transition risk analysis of opportunities and risks

Step 4 Outputs: Company regional transition opportunities and risks, evaluation of aspirational and qualified targets and their enabling conditions, and transition strategies (low-carbon & risk management).

Given that the utility has decided to evaluate and pursue targets (Step 2), they will need to undertake transition risk analysis to identify their opportunities, risks, and risk management strategies for pursuing the ATs and identifying qualified targets (QTs) and their associated conditions.

The utility works through the seven phases associated with the transition risk analysis. The example analysis below informs all of the company's target types. While the company has to analyze targets for the two different GHGs, they can leverage the same scenarios to evaluate the potential size of the future power market, transmission and distribution needs, and the potential SF₆ and CO₂ emissions. From this information, they can then evaluate abatement opportunities and costs for reducing SF₆ and CO₂.

Phase 1: Define reference conditions and itemize uncertainties

- Phase inputs: Previous company planning, strategy, analysis, and risk management experience
- Phase outputs: Scenario analysis reference conditions and list of uncertain factors to consider in scenario design
- Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as possibly external experts on scenario analysis and modeling

- *Documentation: SMARTargets template summarizing reference conditions and uncertain transition factors for scenario design consideration*

For this phase, the illustrative company works with their planning, policy, sustainability, risk management, strategy, and outreach staff, as well as any external experts on scenario analysis and modeling with which they choose to collaborate to define their scenario analysis reference conditions and uncertain factors that they wish to consider in their scenario design in Phase 2.

The key uncertainty for the T&D utility SF₆ and CO₂ emissions categories is the size and composition of the future regional power market. A power market three times the size of today in 2050 can have three times the level of emissions, depending on changes in the generation mix, and a power market half the size of today in 2050 can have approximately half the level of emissions. Similarly, greater use of low-carbon generation, such as renewables, nuclear, and generation with carbon capture, could lower the CO₂ emissions intensity of the electricity moving through the T&D system. Thus, the company will want to discuss potential reference conditions and identify uncertain factors that can influence the size and composition of the power market.

For reference conditions, our illustrative company considers planned builds and retirements. Like the electricity generation utility example, the T&D utility could also include local and federal policy drivers that would be present in all scenarios, such as state renewables goals or clean energy incentives. They might also consider transmission expansion plans in their jurisdiction, grid hardening strategies, retirements of aging lines, upgrades for T&D infrastructure, generator interconnection needs, and any standards they must meet.

The company staff, and any experts involved will develop a list of uncertain factors that they believe are or could be important and that they want to evaluate in some way. For this example, we assume our company identifies the same uncertain factors that were identified in the electricity generation utility example. They could also group their uncertain factors into sets relevant to generation and T&D infrastructure and operations. In addition, the company identified SF₆ abatement technology costs and performance and within region T&D costs, siting, and permitting as additional uncertainties. The list of uncertainties identified are summarized below:

Uncertainties related to the evolution of the electric system (generation)

- Electricity supply decarbonization options,
- Electricity supply technology cost and performance improvements,
- Future electricity demand (load),
- Low-carbon generation technology development and commercialization,
- Low-carbon generation technology permitting,
- Supply chain constraints related to low-carbon generation technologies,
- Not in my backyard (NIMBY) issues,
- Resource procurement,
- Fuel availability,
- Fuel pipeline capacity/augmentation, and
- End-use technology cost and performance improvements.

Uncertainties related to T&D

- Support for new transmission and distribution infrastructure investments,
- New transmission and distribution infrastructure costs,
- New transmission and distribution siting and permitting, and
- Not in my backyard (NIMBY) issues,
- SF₆ abatement costs and performance, and

Note that the SMARTargets Methodology scenario design for T&D utility emissions already accounts for uncertainty about decarbonization transitions—reference (without decarbonization ambition), power sector only, and economy-wide. Like the electricity generating utility, these are relevant to the T&D utility as significant factors influencing potential power market transitions.

At the end of Phase 1, the utility will document their reference conditions and itemize the identified uncertain factors in the SMARTargets Reporting Template.

Phase 2: Create core scenario design – define plausible extreme alternative future conditions

- *Phase inputs: Phase 1 scenario analysis reference conditions and list of uncertain factors to consider in scenario design.*
- *Phase outputs: The company's core scenario design for the required SMARTargets scenarios.*
- *Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as possibly external experts on scenario analysis and modeling.*
- *Documentation after iterations: SMARTargets Reporting Template entries summarizing the core scenario design.*

For this phase, the company continues working with the same team as in Phase 1 to define their core scenario design for the required SMARTargets scenarios. Table BTD5 presents the required core scenarios for T&D utility emissions from the methodology. For evaluating the ATs for T&D utility emissions, the required scenarios are the net-zero scenarios for electricity generation CO₂ targets and the reference scenarios. The reference scenarios help the T&D utility evaluate the power market and SF₆ and CO₂ targets when electricity or economy-wide decarbonization are not pursued. This type of future is a part of the plausible transition space for a T&D utility and therefore should be evaluated. The company will then want to evaluate a range of target levels for SF₆ and CO₂ for identifying their QTs after they review the results for the ATs and reference conditions.

To implement the Table BTD5 scenarios, the company needs to define the conditions—Fuller/More Limited decarbonization options and Facilitating/Challenging other conditions. Recall that the conditions should be intentionally more extreme, but plausible. In this example, we use the same condition definitions that were used for evaluating electricity generation targets (Table BE6). See the electricity generation target example for discussion of the three intermediate steps associated with grouping and defining the Facilitating and Challenging non-climate-policy conditions.

The outcome of the second phase, combining uncertainty categories into sets of conditions and defining the relative conditions, is what is shown in Table BTD6. Table BTD6 is identical to Table BE6 that was used for the electricity generation targets example. The set of uncertainties considered in both the Facilitating and Challenging conditions includes uncertainty regarding electricity generation cost improvements,

electricity capacity additions, electricity transmission additions, fossil fuel prices, and electric technology cost improvements. Note that, Table BTD6 does not include fugitive SF₆ abatement technology cost and performance uncertainty. Note, however, that in the subsequent phases analyzing T&D needs, we consider within region T&D cost, siting, and permitting uncertainty.

With the scenario conditions defined, the company is ready for Phase 3 and the quantification of the alternate conditions. At the end of Phase 2, the company should document their definitions of Fuller/More Limited and Facilitating/Challenging using the SMARTargets Reporting Template.

Table BTD5. Required scenarios for evaluating targets for T&D utility emissions

Target pathway type being evaluated	2050 targets for pathways	Electric sector transition	Economy-wide transition to net-zero in 2050	Decarbonization options	Other conditions
Aspirational Targets (SF ₆ & net CO ₂ ATs and QT > ATs)	SF ₆ 52% & net CO ₂ 100%	Reference (without CO ₂ constraint)	No	N/A	Facilitating
		Reference (without CO ₂ constraining)	No	N/A	Challenging
		Transition to net-zero CO ₂ in 2050	No	Fuller	Facilitating
		Transition to net-zero CO ₂ in 2050	No	More Limited	Challenging
		Transition to net-zero CO ₂ in 2050	Yes	Fuller	Facilitating
		Transition to net-zero CO ₂ in 2050	Yes	More Limited	Challenging
Qualified Targets (SF ₆ & net CO ₂ QTs < ATs)	SF ₆ A, B, C% & net CO ₂ X, Y, Z%	Reference (without CO ₂ constraint)	No	N/A	Facilitating
		Reference (without CO ₂ constraining)	No	N/A	Challenging
		Transition to net-zero CO ₂ in 2050	No	Fuller	Facilitating
		Transition to net-zero CO ₂ in 2050	No	More Limited	Challenging
		Transition to net-zero CO ₂ in 2050	Yes	Fuller	Facilitating
		Transition to net-zero CO ₂ in 2050	Yes	More Limited	Challenging

Table BTD6. Illustrative Fuller/More Limited and Facilitating/Challenging decarbonization condition definitions

Illustrative FULLER decarbonization set

Renewables (wind, solar, bio, hydro)
Nuclear (extensions)
Advanced nuclear (additions)
Fossil
Fossil w/CCS
CDR (biopower w/ CCS & direct air capture (DAC))
Storage
Hydrogen
Biomass carbon neutrality
Other renewable fuels
Low-carbon power imports
Fossil capacity reserves permitted (within emissions constraint)
Demand conservation and energy efficiency

Illustrative FACILITATING other conditions

Reference electricity load growth
Faster electricity generation cost improvements,
Economic electricity capacity additions,
Economic electricity transmission additions,
Lower fossil fuel prices,
Faster electric technology cost improvements

Illustrative MORE LIMITED decarbonization set

Renewables (wind, solar, bio, hydro)
Nuclear (extensions only)
Storage
Electrolytic Hydrogen only
Fossil capacity reserve eligibility declines to zero in 2050
Demand conservation and energy efficiency

Illustrative CHALLENGING other conditions

Faster electricity load growth
Slower electricity generation cost improvements,
Constrained electricity capacity additions,
Constrained electricity transmission additions,
Higher fossil fuel prices,
Slower electric technology cost improvements

Phase 3: Implement scenario design – specify assumptions for scenario modeling

- *Phase inputs: The company's Phase 2 core scenario design for the required SMARTargets scenarios.*
- *Phase outputs: Specification of core scenario design for the company's modeling framework.*
- *Who should be involved: Staff related to planning, sustainability, policy, and strategy, as well as external experts on scenario analysis, modeling, and alternative assumptions.*
- *Stakeholder engagement: This is a good time to seek external stakeholder feedback.*
- *Documentation after iterations: SMARTargets Reporting Template entries summarizing the core scenario design specification.*

For this phase, the company continues working with the same team as in Phases 1 and 2 to specify the core scenario design for their modeling framework. Phase 2 provides the company with everything they need conceptually and qualitatively in terms of the scenarios they want to run. Running the scenarios, however, requires quantification of the scenario design. This includes specifying decarbonization technology cost and performance assumptions, as well as what exactly is meant by “faster” and “slower” cost improvements, and “constrained” capacity and transmission additions. Since we are using the same condition definitions as used for the electricity generation target example, we also use the same specifications (Tables BTD7a and BTD7b are the same as Tables BE7a and BE7b).

Tables BTD7a and BTD7b present an illustrative specification for each of the assumptions associated with the Fuller/More Limited and Facilitating/Challenging conditions. Remember that the specification definitions are intentionally extreme, but plausible, alternative conditions. They are also grounded with justification provided for the specifications.

The utility will also need to define the emissions constraint pathways they will be imposing on the model. These constraints will constrain the model to producing no more than the emissions reductions specified (though the model could produce emissions below the constraints).

After completing Phase 3 is a good time for external stakeholder feedback on the scenario design and specifications. It is an opportunity to discuss setting SMARTargets and the planned transition risk analysis and preliminary future conditions the company is considering.

At the end of Phase 3, the company should document their specifications for their Fuller and More Limited decarbonization options, their Facilitating and Challenging conditions, and their emissions constraints in the SMARTargets Reporting Template.

1

2 Table BTD7a. Illustrative summary of energy technology assumptions

Decarbonization technology cost and performance	Comment/description	Reference
Renewables (wind, solar, bio, hydro), nuclear, advanced nuclear, coal, coal w/ CCS, gas, gas w/ CCS, CDR (biopower w/ CCS, DAC), storage, hydrogen	Engineering-based cost and performance specifications with gradual improvement over time	EPRI (2022b)
Biomass carbon neutrality	Carbon neutral assumption based on analysis of net land use and GHG changes associated with increasing biomass supplies	Blanford et al (2022)
Other renewable fuels	Renewable liquid and gas fuels, including renewable gasoline, diesel, and jet fuel, renewable natural gas, and synthetic natural gas produce with renewable energy	Blanford et al (2022)
Low-carbon power imports	Low-carbon electricity can be exported to other regions via intra-regional transmission	EPRI (2023)
Fossil capacity reserves permitted (within emissions constraint)	Fossil generation capacity can be used to meet capacity reserve requirements but declining emissions constraints over time apply to any generation from that capacity	EPRI (2022b)
Demand conservation and energy efficiency	End-use sectors can reduce emissions through technology and fuel substitution that increases efficiency, as well as reductions in overall use	Blanford et al (2022)

3

4

Table BTD7b. Illustrative specifications for Facilitating and Challenging other condition assumptions

Other conditions	Facilitating	Challenging
Electricity load growth	Reference = load growth due to reference economic and population growth assumptions and electrification due to electric technology relative cost improvements	Faster = reference load growth conditions plus additional data center load growth based on recent trends resulting in 12% greater total load by 2030 (EPRI, 2024)
Electricity generation cost improvements	Faster = default cost projections and reference learning curve for battery cost improvements over time	Slower = higher cost projections by technology and slower learning curve for battery cost improvements over time
Electricity capacity additions	Economic = allows for all economically viable electric capacity to be built	Constrained = limits the building of economically viable electric capacity to historical build rates
Electricity transmission additions	Economic = allows for all economically viable interregional transmission to be built	Constrained = limits the building of economically viable interregional transmission based on historical transmission build rates
Fossil fuel prices*	Lower = No additional supply costs for fossil fuel production beyond the equilibrium cost determined by the energy economy model's balance of supply and demand for each fuel	Higher = Additional supply costs added to fossil fuel production modeling low resource availability or pipeline expansion
Electric technology cost improvements	Faster = Default cost reductions in EV & heat pump components, faster EV adoption reflective of less range anxiety and greater availability of new electric technologies	Slower = Higher component costs for EV & heat pumps, slower EV adoption representative of more range anxiety and less availability of new electric technologies

* The fossil fuel price assumptions in the table reflect the US-REGEN modeling structure. Other economy-wide frameworks might have fixed assumed (i.e., exogenous) energy prices. For instance, they might be based on lower/higher U.S. Department of Energy Annual Energy Outlook fuel price projections.

Phase 4: Identify potential transitions and target implications

- *Phase inputs: Phase 3 specification of core scenario design for implementation in the company's modeling framework.*
- *Phase outputs: Preliminary transition analysis pathways and insights.*
- *Who should be involved: Staff and external experts running the model and processing outputs.*
- *Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.*

For this phase, the company's staff and external experts running the model and processing outputs will work together to develop preliminary transition analysis pathway results and insights. The team will be running the model with the scenario specification implementation developed in phase 3, and they will have to debug and likely revise the scenario specification implementation as they attempt to run each of the scenarios in the design. They will also want to review the results for non-intuitive, or otherwise

problematic, outcomes that could be an artifact of an incorrect scenario specification or implementation. The team would want to revise and rerun scenarios in these cases as well.

In addition to running the scenarios, the team will develop preliminary graphics—figures and tables—and identify preliminary insights for review. In particular, the team will want to evaluate differences and similarities in transition results between scenarios. The differences between the scenarios are the most meaningful insights, not the specific values from individual scenarios, as you will learn something about the direction and order of magnitude of implications for the different conditions. For instance, T&D utilities would be interested in the alternative potential transitions for the electricity market size and generation composition, transmission and distribution needs, emissions, and abatement costs for each emissions category. The modeling provides information regarding the alternative potential transitions, trade-offs, uncertainty, risks, enabling conditions, robust strategies, contingencies, and more. Below we present sample results for the company’s scenario design. For this example, we are evaluating potential market transitions for a company in the midwestern U.S. These results represent potential alternative market and operational conditions for the company’s system and assets.

The overall approach is, for each emissions category, to first estimate the future T&D needs under the different scenario conditions and then the associated emissions, after which the company evaluates target setting. For fugitive SF₆ emissions, we evaluate targets by applying marginal abatement cost curves to estimate costs for a range of emissions reduction levels for a given power market. For both CO₂ emissions categories, purchased energy and transmission and T&D line losses, we evaluate targets using the scenario modeling emissions results from which costs can be estimated using the resulting CO₂ prices.

Future T&D needs

The utility begins by assessing the T&D transition needs for the different futures. The T&D utility is primarily interested in the implications of decarbonization on current T&D assets and the need for new infrastructure. The utility can assess needs based on the projected electricity generation transitions. Figure BT2 shows the electricity generation size and mix across the required scenarios. The figure is the same as Figure AE2 from the electricity generation utility example. In 2035 and 2050, there is significant variation in the generation from variable renewables (wind and solar) across the scenarios, with variable renewable resources potentially as high as 70% and 90% of annual generation respectively. The results also show that, by 2035, load growth could be as high as 25%, and by 2050, as high as 80%. The results indicate that, as early as 2030, grid enhancements are required to accommodate growing load and largescale deployment of renewables. The T&D utility, therefore, would want to consider how they can manage growth in load and renewables while managing the risk associated with the uncertainty evident in Figure BT2.⁵

⁵ Recall that these scenarios evaluate potential load increases due to growing data center demand.

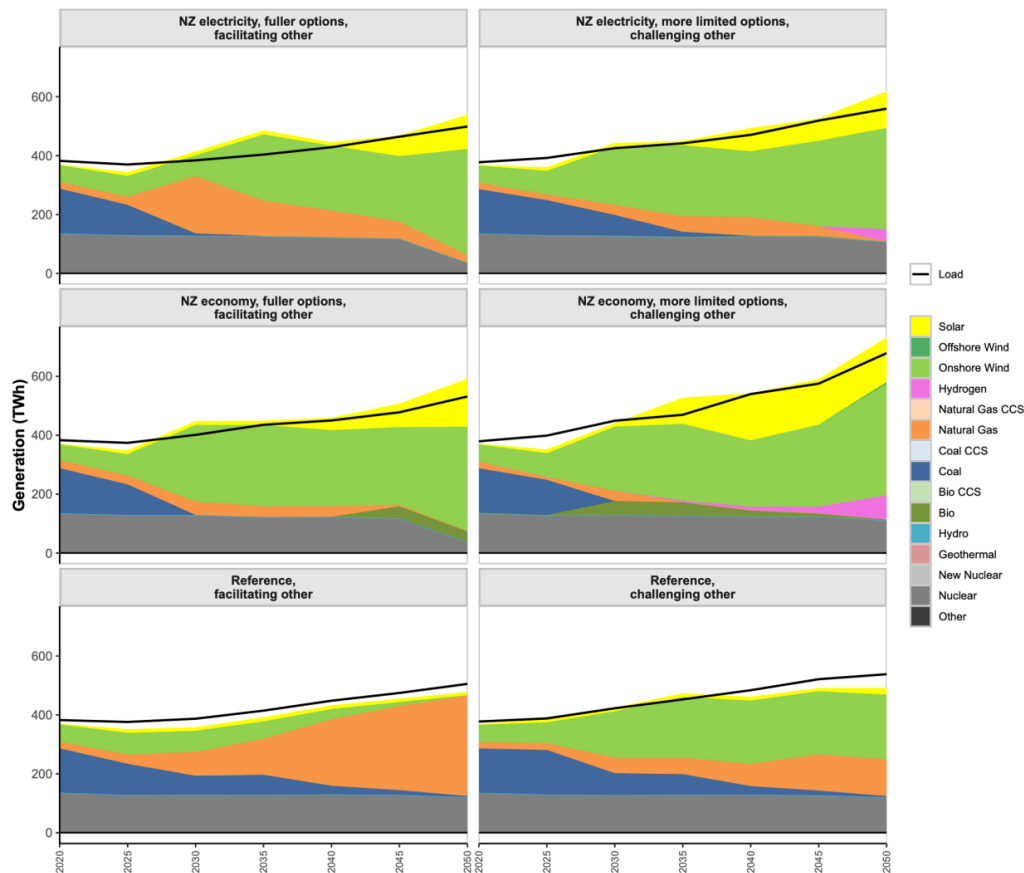


Figure BTD2. Regional electricity generation and load transitions

Source: EPRI analysis

Figure note: See Figure AE2 note.

Future potential inter-regional power trade is also important to understand given the use of transmission assets. Figure BTD3 shows the power imports into and exports from the region. As indicated in the figure, electricity trade varies across scenarios and over time. Electricity imports help serve load, while exports provide additional revenues to generation resources. As shown in the figure, power trade volumes increase notably in the decarbonization transitions versus Reference futures. We also see that in the decarbonization transition futures, imported power is, in most cases, larger than exported power, suggesting that the region is leaning harder on imports than exports when decarbonizing.

In addition, within region T&D needs also need to be evaluated. Grid enhancements and expansions are needed to support the growth in renewables and load, as well as to alleviate congestion and improve the reliability and resilience of the existing system. In this example, the US Midwest utility can utilize the scenario analysis results as well as other transmission expansion information to assess their within region T&D needs.⁶ Most transmission expansion plans do not currently project out to 2050 and/or do not consider economy-wide and cross-region deep decarbonization. Thus, the SMARTargets transition

⁶ For example, [MISO Transmission Expansion Plan](#).

1 analysis provides the utility with a bigger and broader strategic picture of potential transitions and T&D
2 needs.

3
4 Figure BT4 shows the intra-regional transmission needs assessed by a multi-model scenario study that
5 considered possible decarbonization futures (DOE, 2023).⁷ The variable renewable penetration and load
6 growth results from our transition analysis are similar to the levels considered in the DOE (2013)
7 Moderate/Moderate scenario.⁸ According to the DOE study, the Midwest region had 11.92 Terawatt-miles
8 (TW-mil) of transmission capacity in 2020. By 2035, the study projects an increase in within-region
9 transmission needs of 19% to 174% depending on whether there is moderate load growth and moderate
10 renewable penetration or high load growth and high renewable penetration. By 2040, the study projects
11 that transmission needs could increase by 29% to 196%.

12
13 Rough estimates of the investment requirements for this kind of transmission capacity expansion ranges
14 from \$2.3 to \$6.8 billion in 2035 and from \$3.4 to \$10.6 billion in 2050 if using high voltage lines (HV), and
15 from 4.5 to 11.3 billion in 2035 and 6.8 to 17.0 billion in 2050 if done with ultra-high voltage lines (UHV).
16 The latter have several benefits specially for long-range transmission that could help connect renewable
17 resources to distant load centers, as well as help reduce transmission losses.⁹

⁷ The U.S. Department of Energy (DOE) is required to update this analysis of transmission needs every three years and could serve as a basis for estimating grid expansion needs.

⁸ The moderate/moderate scenarios consider a moderate penetration of renewable energy of less than 80% and moderate load growth less than 71% from 2021 levels (3974 TWh in 2021 to 7000 TWh in 2040). The DOE study also provides transmission needs estimates for higher renewables penetration and load growth.

⁹ High-voltage transmission lines (230 and above) typically ranges from \$1 million to \$3 million per MW-mile, while ultra-high voltage lines (500 kV and above) ranges from \$2 million to \$5 million per mile (De Santis et al 2021).

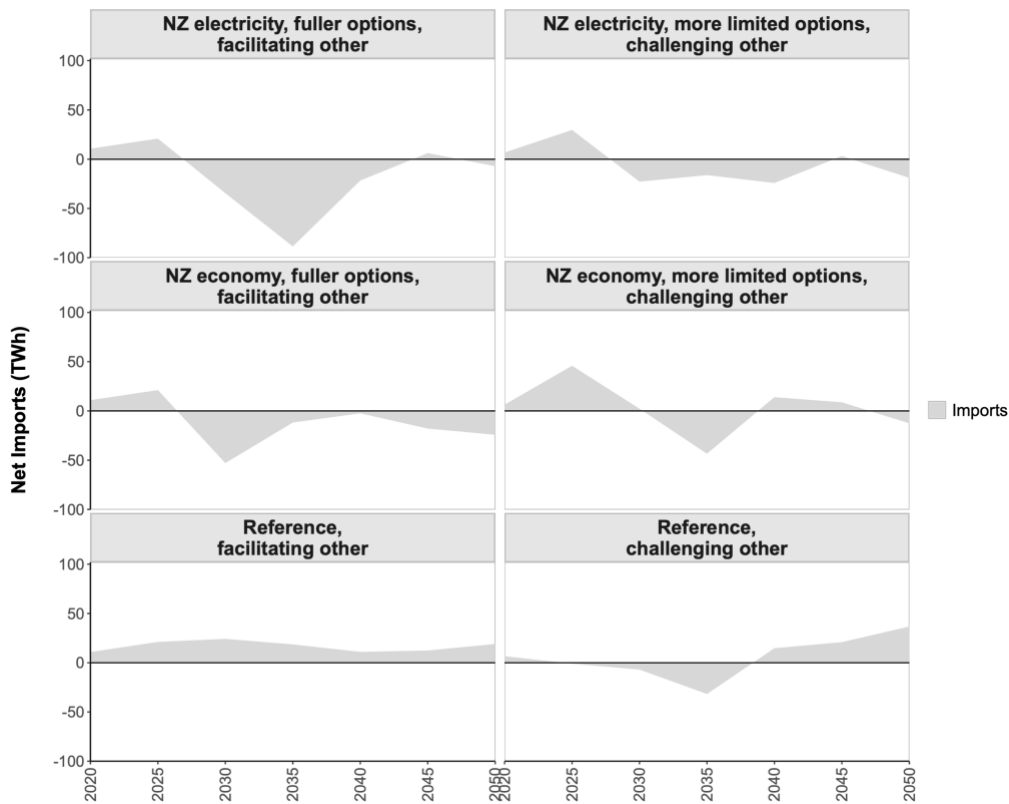
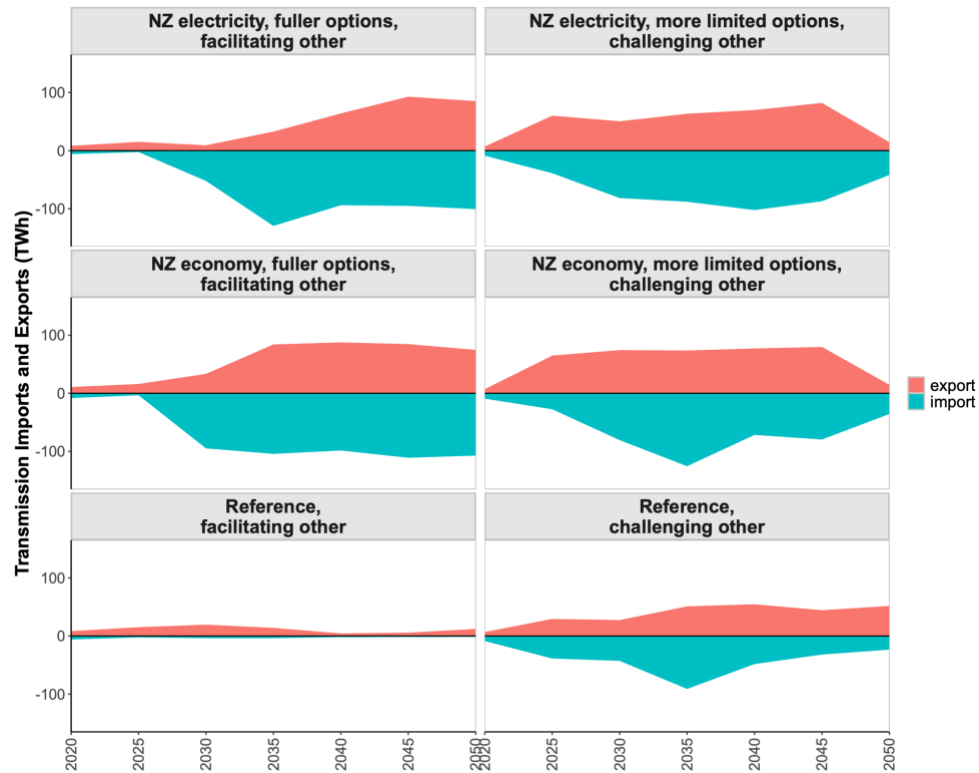


Figure BT3. Potential inter-regional electricity imports and exports (top) and net imports (bottom) in the required scenarios

1 In our example, the utility should estimate the within region infrastructure expansion needs to support
2 the projected transitions. Expansions of at least 20% by 2035 and 30% by 2050 are supported by the DOE
3 (2023) study in combination with the transition scenario modeling results for renewables and load.
4 Investment in HV versus UHV lines could be determined by further exploring the long-range transmission
5 needs and the reduced transmission loss benefits. Even larger expansions of T&D infrastructure are
6 suggested by the extreme DOE (2023) scenarios with 80% load growth and 94% renewables integration.
7 Transmission infrastructure expansion in this case could be as much as 57% by 2035 and 115% by 2050.

8
9 Enhancements of distribution infrastructure should also be evaluated, particularly in scenarios where
10 electrification of energy end-use increases and when distributed energy resources (DER) are a larger share
11 of the energy mix. Investments in smart grid technology that enables bi-directional flows of energy and
12 demand response would be important for an efficient grid and to help integrate DER. US-REGEN does not
13 model the details of the distribution grid; however, insights for assessing distribution needs can be derived
14 from the electrification results for transport, buildings and industry. Figure BT5 shows potential
15 electricity consumption by sector and transition scenario. Electrification consumption increases in all
16 scenarios particularly for transportation but varies across the potential futures, with the economy-wide
17 decarbonization futures resulting in the largest increases in electricity consumption. Detailed studies of
18 the need for distribution infrastructure could be conducted based on this information, with DER
19 considered as an estimated fraction of solar resources.
20

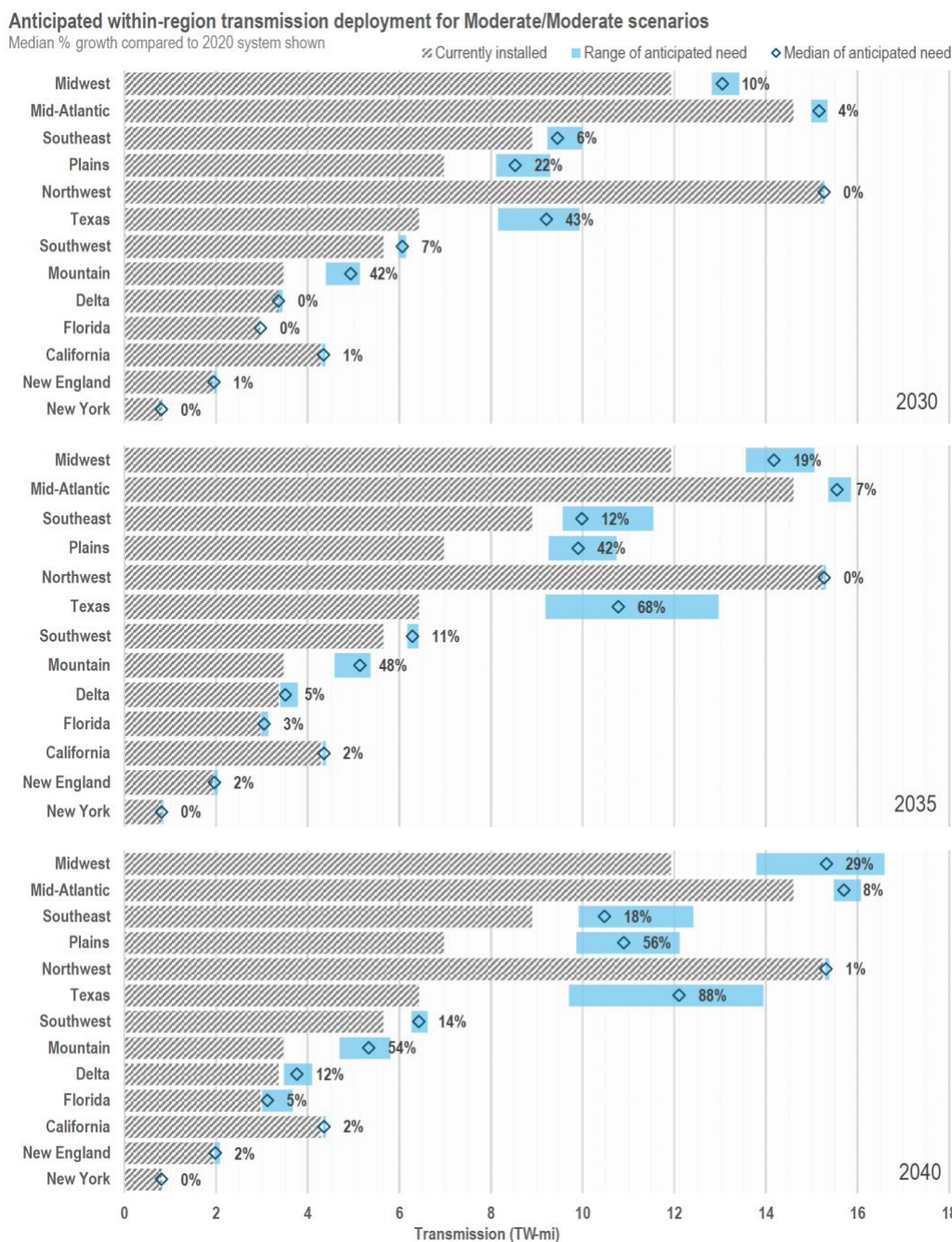


Figure BTD4. U.S. within-region transmission installed and needed in DOE (2013) decarbonization futures

Figure note:

- New transmission relative to 2020 system is shown for all regions for 2030 (top), 2035 (middle), and 2040 (bottom). Median and interquartile range (IQR) of new transmission results shown. Currently installed transmission shown from Denholm et al (2022a).
- Moderate/Moderate scenario is defined as moderate load growth from the 2021 baseline (3,974 TWh) to 7,000 TWh in 2040 and moderate clean energy penetration from the 2021 baseline (38.6%) to 80% in 2040. 2021 values from EIA (2022a).

Source: DOE (2023)

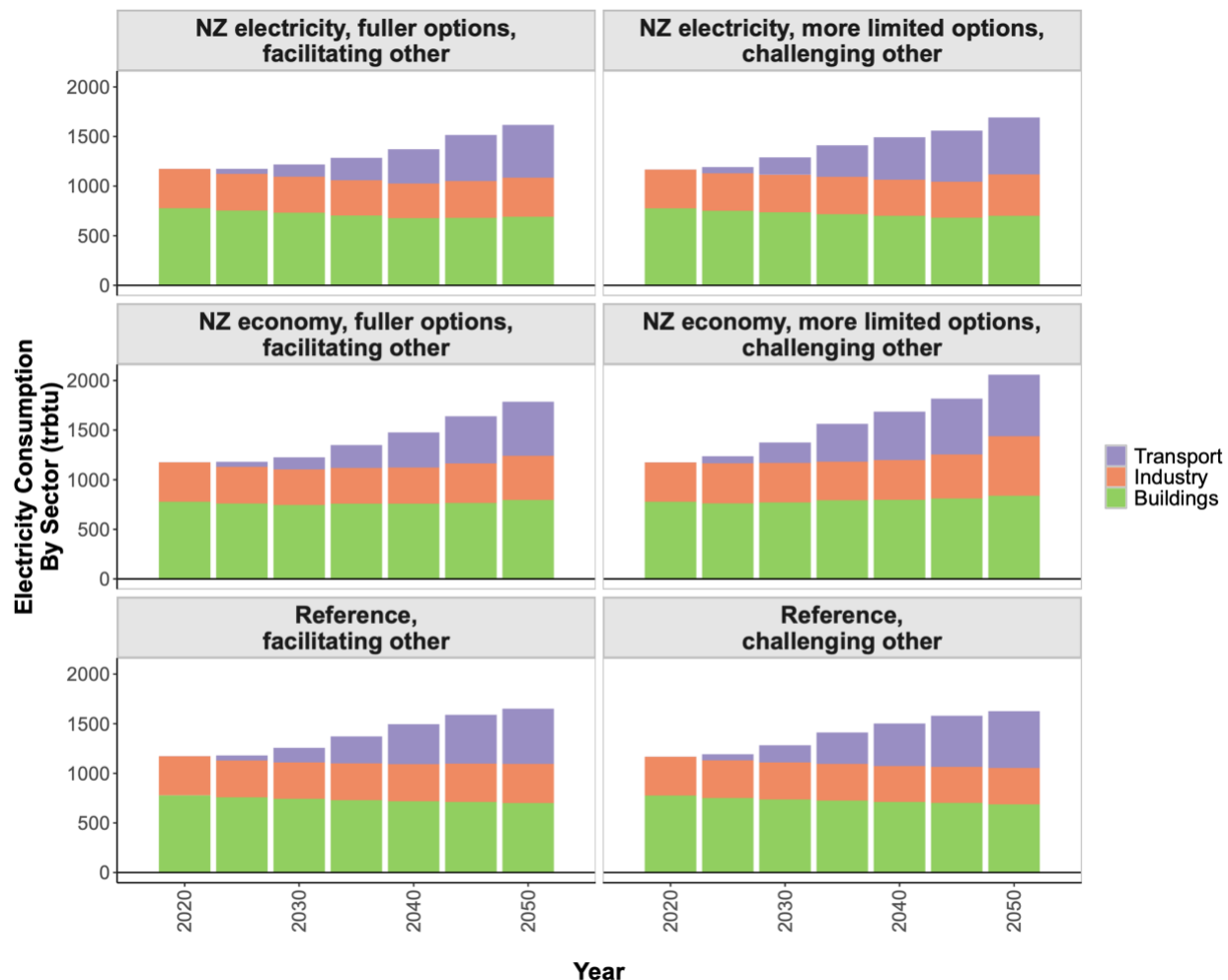


Figure BTD5. End use electricity consumption by sector for the required scenarios

Future emissions without targets

Once the utility team has a good understanding of potential T&D needs for each scenario, they can translate those to future emissions. The power to serve load CO₂ emissions pathways emerge directly from modeling the power sector transition and emissions with and without decarbonization,¹⁰ but it is necessary to do additional calculations to compute the transmission loss CO₂ and fugitive SF₆ emissions. For the former, we use state data on average grid power losses from the states in the region (IEA, 2024), which is an average of 4% for this Midwest region. For the latter, we use US-REGEN data of expected load growth to project T&D requirements and SF₆ use.

Figure BTD6 presents the 2030 and 2050 CO₂ and SF₆ emissions in percentage change terms (relative to 2015). CO₂ emissions decrease as the grid decarbonizes. While transmission losses cannot be fully

¹⁰ We assume the utility is a 'wires-only' company that does not own generation assets, and that all electricity consumed in the service area is delivered using the company's infrastructure.

eliminated, losses will not translate into emissions if the power fed into the grid is clean. If generators decarbonize to net zero, the T&D utility has no additional action since the net-zero CO₂ targets would already be reached. However, if the generators do not fully decarbonize, the T&D company would have to pursue additional reductions with the generators and by reducing line losses. In the meantime, all the scenarios project increasing SF₆ emissions. This result is due to load growth and the expansion of renewable energy, both of which require more T&D infrastructure regardless of the future. SF₆ emissions are projected to increase significantly across all scenarios, with the most pronounced growth occurring in the 'Net Zero Economy-wide, More Limited Options, Challenging Other' scenario. This scenario has the highest demand for electricity due to the demand for low-carbon electricity created by the economy-wide emissions constraint, as well as data center load growth and the More Limited Options resulting in greater dependence on electricity in decarbonizing the whole economy. The scenario also has the largest growth rate in renewable generation capacity greatest of all the futures. These factors together translate into greater T&D requirements and more SF₆ emissions than the other scenarios.

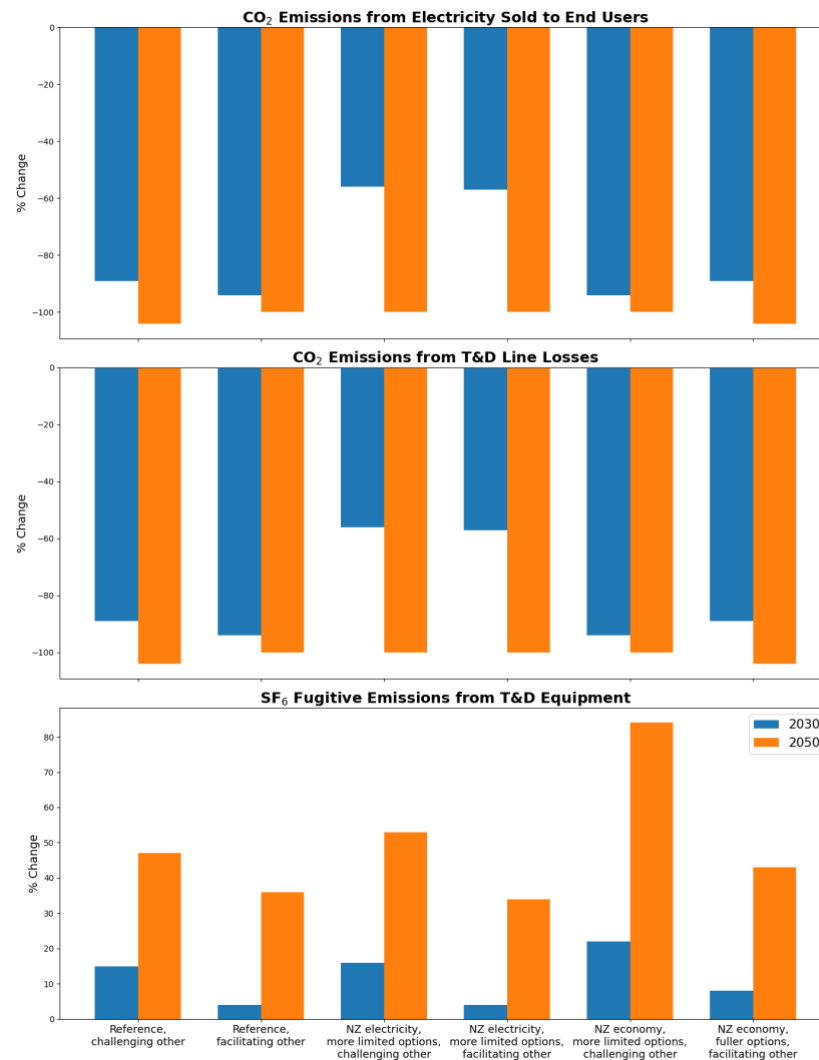


Figure BTD6. Percent reductions in regional emissions in 2030 and 2050 from power to serve load, T&D losses, and Fugitive SF₆

Target evaluation

With the emissions projections by scenario, the company can now evaluate target setting. For fugitive SF₆ emissions, the company can evaluate targets by applying marginal abatement cost curves to estimate costs for a range of emissions reduction levels. For CO₂ from energy to serve load and T&D losses, the company can evaluate targets using the scenario modeling results for emissions from which costs can be estimated using the implied CO₂ prices.¹¹

There are a variety of abatement measures that can be applied to fugitive SF₆ emissions from T&D systems (EPA, 2019, Table BTD8). For reducing SF₆ emissions the utility can target four streams of emissions:

- **Handling:** Emissions can result from improper handling of SF₆ during the maintenance of gas-insulated circuit breakers. Abating these emissions can be low cost and implies training technicians to properly handle the gas and purchasing adapter kits to ensure proper fittings are available for connecting hoses to all gas-insulated equipment throughout the system.
- **Venting:** Emissions result from venting during equipment maintenance and disposal. These emissions can be abated by increasing SF₆ recycling and reuse. It requires investment in SF₆ reclamation and equipment for purifying for reuse.
- **Periodic leakage:** Emissions result from periodic leakage from equipment. These emissions can be abated by leak detection or repair options (thermal imaging camera and hand-held gas detectors).
- **Chronic leakage:** Emissions result from chronic leakage from equipment. These emissions can be abated by equipment replacement or use of SF₆ free gas insulated equipment.

Table BTD8. SF₆ abatement options and example costs

Source: EPA (2019)

Table note: The first row of each option refers to an uncontrolled system (e.g. in developing countries), and the second row refers to a controlled system (e.g. Europe and North America).

Abatement Option	Project Lifetime (years)	Capital Cost (2010 USD)	Annual Revenue (2010 USD)	Annual O&M Costs (2010 USD)	Abatement Amount (tCO ₂ e)
SF ₆ recycling	15	\$520,156	\$101,919	\$7,592	44,678
		\$78,023	\$1,716	\$20,097	2,048
LDAR (Thermal Imaging Camera)	5	\$20,700	\$1,887	\$151	827
		\$49,615	\$238	\$3,468	284
LDAR (Handheld Leak Detector)	5	\$1,387	\$7,550	\$1,557	3,309
		\$693	\$238	\$7,458	284
Equipment Replacement	40	\$2,886,599	\$17,930	-	7,860
		\$2,844,205	\$1,811	-	2,161
SF ₆ -free Gas Insulated Equipment	50	\$4,328,671	\$17,930	-	7,860
		\$4,373,246	\$1,811	-	2,161
Improved SF ₆ handling	1	\$4,369,910	\$1,029	-	1,228
		\$14,671	\$135,893	\$358	59,570

¹¹ In 2050, the implied CO₂ prices range from \$130 to \$1,330/tCO₂. The lower price is associated with Fuller-Facilitating conditions, while the higher price is associated with More Limited-Challenging conditions.

Estimates of abatement costs for the set of measures can be used to evaluate emissions reduction opportunities; however, the company will need to consider which technologies apply given their system. For illustrative purposes, we use a representative curve (Figure BT7) of marginal abatement costs for reducing SF₆ emissions in the U.S., in 2030 and 2050.

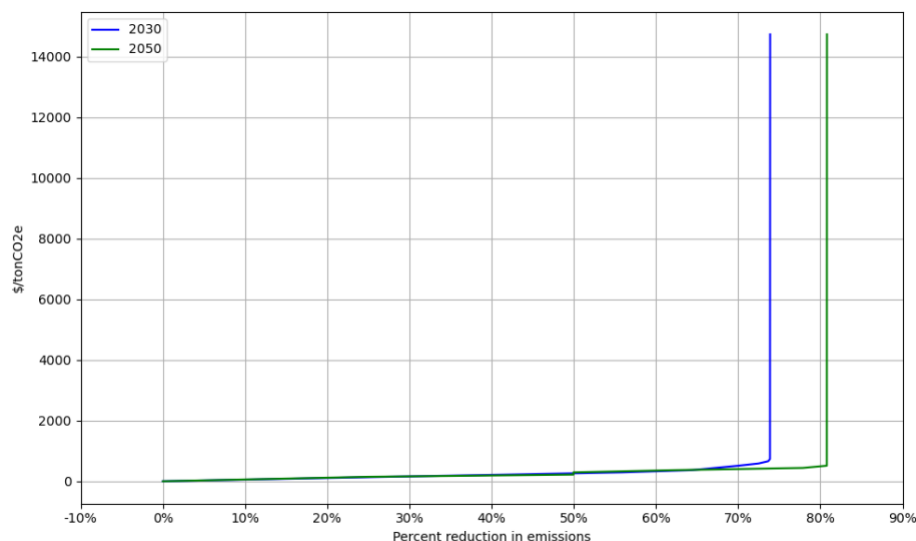


Figure BT7. Example marginal abatement cost curves for SF₆ emissions in the U.S. in 2030 and 2050

Source: Harmsen et al 2019.

Figure note: Data for 2030 and 2050 plotted by EPRI and converted to \$/tCO₂e. The original dataset provided by Harmsen et al. (2019) covers 2000 to 2100 in 10-year increments for several countries.

The marginal abatement cost estimates are applied to the alternative SF₆ emissions transition results (Figure BT6) to assess the costs of achieving the ATs (Figure BT8). Figure BT8 presents the net present value abatement costs for meeting the ATs under each scenario for all three emissions categories. These costs reflect the incremental abatement required given the emissions associated with each future (Figure BT6).

Because of the increasing SF₆ emissions in all the scenarios, the utility will have to abate SF₆ in each case and incur costs. Abating the CO₂ categories, on the other hand, is a different story since CO₂ reductions occur in most of the scenarios, thereby reducing, if not eliminating, the utility's abatement requirements for meeting the CO₂ ATs. The CO₂ abatement costs in Figure BT8 are derived using the implied CO₂ prices needed to achieve decarbonization in the various futures. As shown in Figure BT6, only the Reference scenarios require additional abatement. This suggests that the CO₂ targets are achievable if electricity generation decarbonizes at the implied pace. However, without power sector or economy-wide decarbonization, the T&D utility will have to implement abatement measures for the ATs to be met.

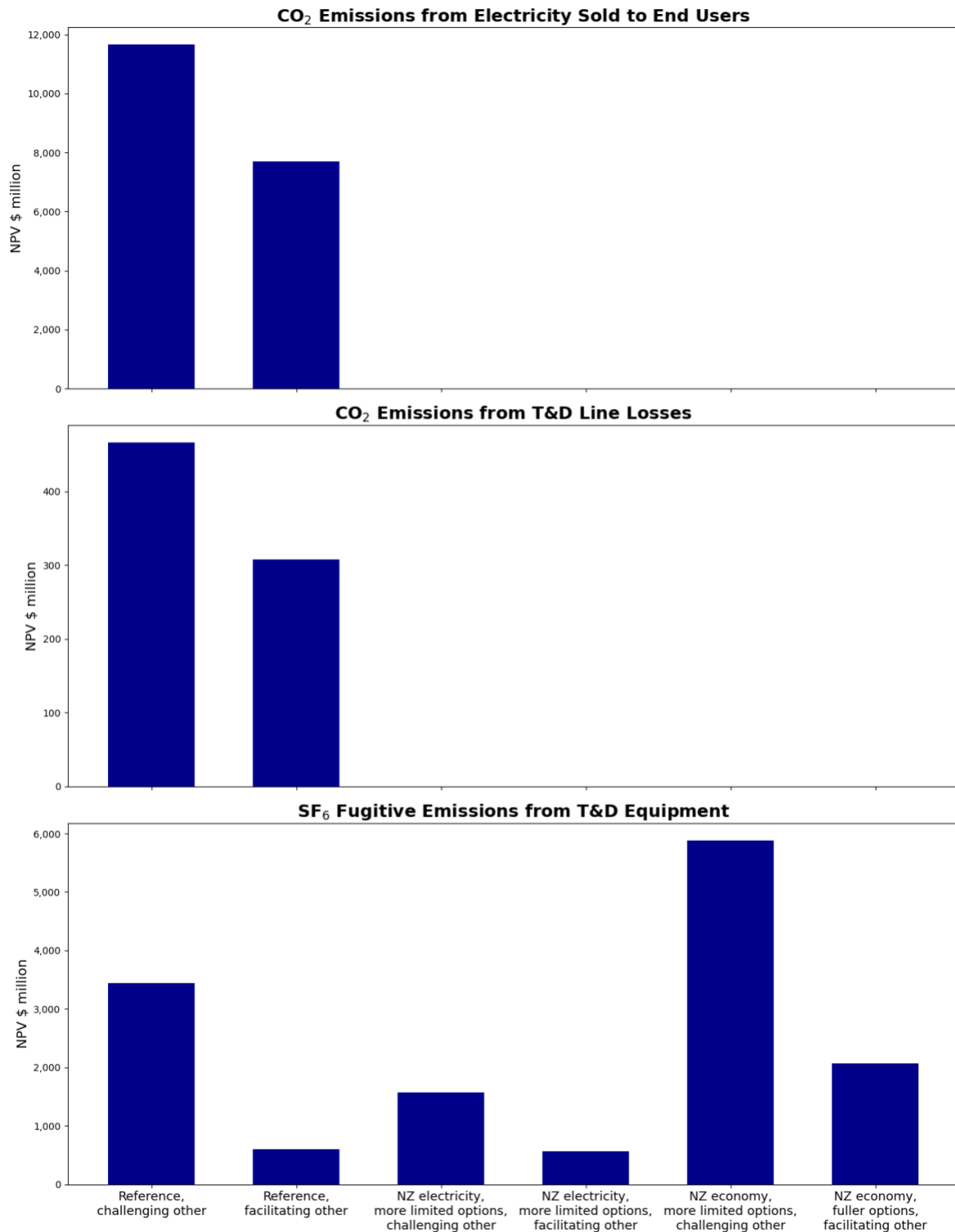
Uncertainty in the electricity market (Figure 2) leads to considerable variation in the cost of meeting emissions targets for T&D utilities (Figure BT8). For CO₂, the net present value (NPV) cost of achieving net-zero emissions by 2050 from electricity sold to end users ranges from \$0 to \$11,661 million. Similarly, the cost of eliminating emissions from T&D line losses ranges from \$0 to \$466 million. These differences stem from the large variation in CO₂ emissions in the different futures, which the decarbonization transitions reducing emissions to AT levels or beyond and the reference transitions resulting in significant

emissions that need to be abated. The Reference-Challenging conditions are the most expensive due to the electricity load growth from data centers and slower improvements in generation costs.

In the case of SF₆, the NPV costs of achieving a 52% reduction by 2050 range from \$562 million to \$5,886 million. Lower-cost outcomes are associated with scenarios featuring smaller electricity markets, such as Reference–Facilitating and Net-Zero Electricity–More Limited–Facilitating. In both cases, the Facilitating slower load without data center growth is a key factor. In contrast, the highest costs are observed in scenarios with larger electricity markets and greater infrastructure needs, such as the Economy-Wide Net Zero–More Limited–Challenging scenario. In these futures, rising electricity demand for end use decarbonization drives T&D infrastructure expansion and increased SF₆ use. Without viable SF₆-free alternatives, emissions from this category are likely to grow—even if handling and monitoring practices improve.

These findings underscore the importance of enabling conditions for SF₆ abatement. Abatement technological improvements or new abatement options can help manage the risk of higher-cost outcomes. While reducing transmission expansion also lowers abatement costs, it would also affect broader economy-wide decarbonization since T&D infrastructure is essential for integrating low-carbon resources into the grid. Facilitating conditions, such as innovation and reduced infrastructure additions barriers, can help reduce costs for both CO₂ and SF₆: supporting a more affordable transition to lower emissions.

As shown in Figure BTD9, some futures are challenging for achieving the CO₂ and SF₆ ATs. As a result, the company will want to assess the level of emissions abatement achievable under the less favorable conditions. Figure BTD9 presents incremental net present value abatement costs for each emissions category. For SF₆, reduction pathways leading to 10%, 20%, and 30% reductions in 2050 are evaluated, along with the 52% in 2050 AT. For CO₂, reduction pathways leading to 30%, 50%, and 80% reductions in 2050 are evaluated, along with the 100% in 2050 AT. For all three emissions categories, costs increase with the level of reduction. However, the magnitude of the costs and rate of increase with reduction ambition vary depending on the emissions category and the conditions.



1

2 [Figure BTD8. Net present value abatement costs for reaching the CO₂ and SF₆ Aspirational Targets](#)

3 Figure note: Y-axis' units vary by chart.

1 The company can use the analysis of incremental costs (Figure BTD9), to identify their QTs and associated
2 conditions. The utility can identify a cost threshold for reductions based on their regulatory environment
3 and use that information to identify QTs and conditions. For example, for SF₆, a \$2 billion threshold would
4 imply that 52% reductions would be challenging in reference or economy-wide decarbonization futures
5 with Challenging other conditions. If these conditions emerge, Figure BTD9 identifies QTs of
6 approximately 45% and 30% in 2050 respectively. Since the results in Figure BTD9 are for the region, the
7 company would scale them for their system, utilizing the implied growth rates and/or their market share,
8 to help them consider their company-specific cost thresholds. Not knowing which future will emerge, the
9 utility could specify both as sets of QTs with pre-2050 and 2050 targets. The figure also highlights that the
10 Facilitating conditions are enabling conditions, lowering the cost of SF₆ abatement in every context versus
11 its Challenging counterpart.

12 Similar insights can be derived for the CO₂ categories. For instance, if there is \$2 billion threshold here as
13 well, the figure highlights that a net-zero target in 2050 for CO₂ from power to serve load is likely very
14 challenging in both reference futures. However, QTs of approximately 65% and 85% 2050 targets could
15 be pursued in the Challenging and Facilitating reference futures respectively. The utility could use this
16 information to consider company-specific cost thresholds and potentially specify two set of QTs for the
17 CO₂ categories or, given that the lower QT is associated with Challenging conditions, they might simply
18 choose 65% in 2050 and note that Facilitating conditions would enable them to pursue greater reductions.

19 The regional costs for abating CO₂ from T&D line losses are modest in comparison to the other categories.
20 Nonetheless, the utility can utilize the figure to consider QTs for the reference futures. In this case, we
21 assume that the regional costs of \$450 million for near 100% reductions by 2050 is not prohibitive, and
22 the utility does not need QTs for this category. This of course recognizes that line losses cannot be
23 eliminated entirely.

24

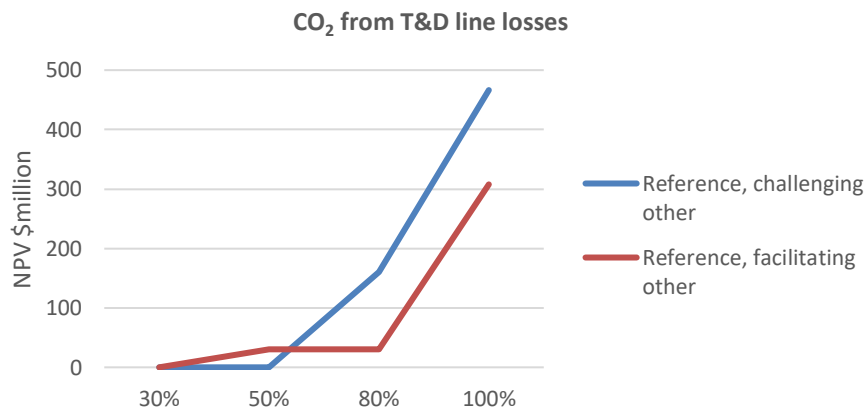
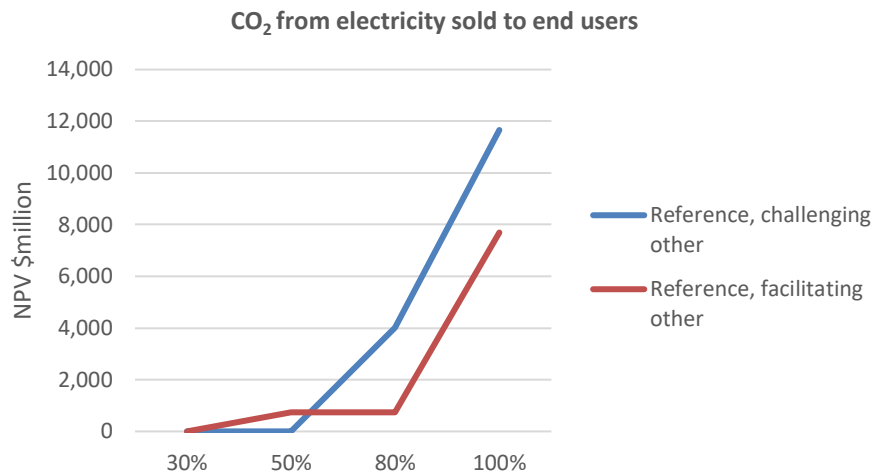
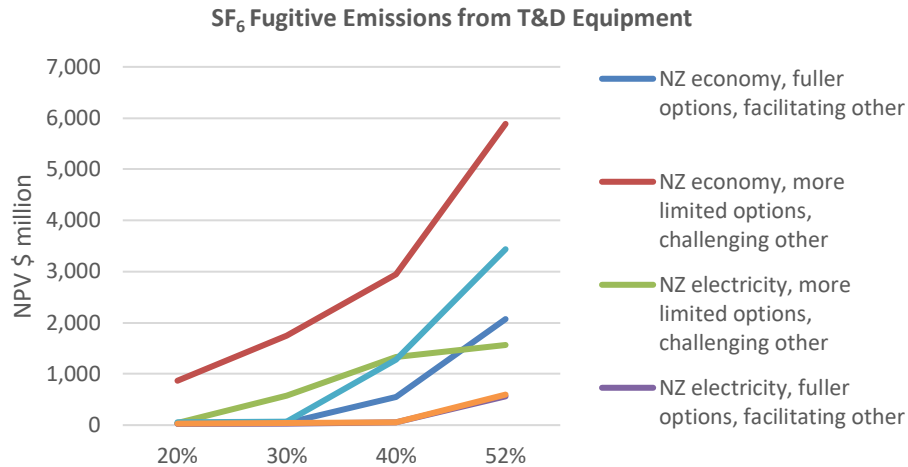


Figure BTD9. Incremental net present value costs for increasing emission reduction targets in 2050 for T&D fugitive SF6 emissions (top row), CO2 from power to serve load (middle row) and CO2 from T&D losses (bottom)

Figure note: Y-axis' units vary by chart. In the SF6 chart, the NZ electricity-Fuller-Facilitating cost curve coincides with the Reference-Facilitating curve.

Phase 5: Review potential transitions and target implications – based on decision-making needs

- *Phase inputs: Phase 4 preliminary transition analysis pathways and insights.*
- *Phase outputs:*
 1. *Preliminary insights regarding potential transitions, targets, and risks,*
 2. *Revisions to core scenario design, model implementation, and output reporting, and*
 3. *Additional recommended and sensitivity scenarios and specifications the company would like to evaluate.*
- *Who should be involved: Company decision-makers (e.g., directors, executives), staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.*
- *Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.*

For this phase, the company’s planning, policy, sustainability, risk management, strategy, and outreach, staff, as well as external experts, will want to engage the company’s decision-makers—directors and executives. The main objective here is to critically evaluate and discuss the preliminary results and insights and identify those they find reliable and meaningful. The additional objectives here are to identify any revisions to core scenario design, model implementation, and output reporting they might want to make, and to identify sensitivity scenarios and specifications that the company would like to evaluate. The last two items emerge from the company’s critique and discussion of the draft results and insights.

Given the need to identify enabling conditions, this is the time for the company to think concretely about trade-offs, risks, and risk management from their perspective. The Phase 4 discussion above highlighted related insights from the perspective of our example company and analysis, noting specific risks and enabling conditions that identify and justify the company’s QTs. Using the results from Phase 4, the company identifies trade-offs, risks, and risk management strategies. For instance:

- *Risks identified:* The primary risk is the power market (size and generation resources), which is not only a risk in terms of the emissions abatement challenge, but also an overall investment, revenue, and operations risk for a T&D utility. Related to power market risk, there is abatement cost and target attainability risk, where we find that there is the possibility of significantly higher costs associated with achieving the ATs in some plausible future conditions, especially for 52% reductions in fugitive SF₆ emissions by 2050 and 100% reductions in CO₂ from power to serve load.
- *Risk sources:* All categories of uncertainties create risk for the company. Thus, uncertainty regarding the decarbonization incentive (none versus sector versus economy-wide), decarbonization options (Fuller versus More Limited), and Other conditions (Facilitating versus Challenging) are all important considerations contributing to uncertain transitions with some more difficult to manage trade-offs in load growth, traded power, and emissions from purchased power to serve load. Uncertainty about the decarbonization transition alone creates risk for the CO₂ targets because the company does not know if they will have no or significant abatement costs. Similarly, for SF₆, while all the futures imply abatement costs, the costs for achieving the ATs ranges from \$500 million to \$6 billion. And, Challenging conditions make the cost of abatement higher for all the emissions categories. It is important to recognize that revenue recovery for T&D infrastructure is essential, and tariff schemes should reflect the critical role of T&D in supporting decarbonization efforts.

- *Risk management strategies:* Looking across the scenarios, we can identify enabling conditions and contingencies. We find that economy-wide decarbonization incentives, Fuller decarbonization portfolios, and Facilitating Other conditions result in greater and faster decarbonization of power generation and therefore help manage the risk for CO₂ targets for T&D line-loss and electricity sold to serve load. R&D lowering the costs of line efficiency improvement measures are also practical strategies for helping lower line-loss CO₂ abatement costs, while R&D lowering SF₆ abatement technology costs will help manage SF₆ abatement costs. Pursuing Facilitating Other conditions is also found to be a risk management option for SF₆ targets. As for contingencies, if the company finds themselves in an economy-wide decarbonization future with More Limited and Challenging conditions, they may have to reconsider a 52% SF₆ target, unless lower cost SF₆ abatement technologies have emerged or offsets are available. For CO₂ targets related to line losses and sold power, the company depends on external electricity generators to achieve compliance. In the Reference futures—where no emissions targets are imposed on generators—setting lower reduction targets may be all that is possible given the cost challenge, especially under Challenging conditions. For all three emissions categories, pursuing Facilitating conditions, such as faster technology cost improvements and reduced barriers to new additions, will support greater emissions reductions and help manage abatement costs.

This phase is also the time when the company would want to consider the likelihoods of the different futures and potential hedging strategies they might pursue. For example, if the company believes that the likelihood of an economy-wide policy is low and Challenging conditions are more likely than Facilitating, they might want to invest more in R&D for reducing T&D line losses and abating fugitive SF₆ emissions, as well as explore and communicate what emissions reductions are possible if they cannot bring the abatement costs down.

After developing preliminary results and insights, the company would want to identify whether revisions to the scenario design, model implementation, and/or output reporting. In terms of identifying potential revisions to the scenario design and implementation in particular, the group discussion should consider whether they want to tweak anything. This could include revising what is included in each of the Fuller and More Limited decarbonization options sets, making Facilitating/Challenging more extreme to further differentiate them, or simply adjusting a specification such as the annual additions constraints for new transmission.

The company discussion on potential sensitivity scenarios should look for meaningful adjustments to one or two assumptions. For example, based on the results above, this company might want to consider running more sensitivities to load growth and transmission constraints and/or evaluating potential improved grid enhancement or improvements in SF₆ abatement technology costs.

Like Phase 4, outside of noting that they completed this phase, there is no documentation requirement for the company since it is an intermediate phase. SMARTargets requires documenting the final modeling results and insights in Phase 7 once iterations are complete.

Phase 6: Revise and iterate as needed – revising scenario design, implementation, and model results

- *Phase inputs:*

1. *Phase 5 revisions to core scenario design, model implementation, and output reporting, and*
2. *Phase 5 sensitivity scenarios and specifications the company would like to evaluate.*

- *Phase outputs:*

1. *Revised insights regarding potential transitions, targets, and risks, and*
2. *As needed, additional revisions to scenario design, model implementation, and transition pathways.*

- *Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.*

- *Stakeholder engagement: This is a good time to seek external stakeholder feedback.*

- *Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.*

For this phase, the company's planning, policy, sustainability, risk management, strategy, and outreach, staff, as well as external experts, will work together to revise the insights regarding potential transitions, targets, and risks, and, as needed, implement any needed revisions to the scenario design (core and sensitivity scenarios), model implementation, and transition pathways.

For this phase, our company continues to iterate on the scenario design, specification, results, and insights until they have agreement with their decision-makers.

Phase 6 is also a good time for external stakeholder feedback, especially given the important role of stakeholder consultation in T&D planning. After internal iterations are complete, the company will have final drafts of their scenario design, results, insights, and strategies to share and discuss. This gives the company an opportunity for education and dialogue, as well as an opportunity to solicit feedback on their potential transitions, challenges, uncertainties, risks, enabling conditions, and collaboration opportunities.

For this phase, the company continues to iterate on the scenario design, specification, results, and insights until they have agreement with their decision-makers. Like Phase 5, outside of noting that they completed this phase, there is no documentation requirement for the company since it is an intermediate phase. SMARTargets requires documenting the final modeling results and insights in Phase 7 once iterations are complete.

Phase 7: Communicate results – targets, transitions, risks, enabling conditions, risk management

- *Phase inputs:*

1. *Phase 6 final scenario design (core and additional scenarios), model implementation, and transition pathways, and*
2. *Phase 6 final insights regarding potential transitions, targets, risks, enabling conditions, and risk management.*

- *Phase outputs:*

1. *Documented scenario analysis, outputs, and insights,*
2. *Aspirational Targets (ATs), strategies, and risk management, and*
3. *Qualified Targets and their qualifying conditions (QTs) and strategies.*

- *Who should be involved: The company’s decision-makers (e.g., directors, executives), staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.*

- *Documentation: SMARTargets Reporting Template summarizing the following:*

1. *The company’s ATs and QTs with corresponding conditions,*
2. *The company’s enabling conditions, strategy, risks, and risk management,*
3. *The company’s transition risk analysis (modeling, scenario design and specification, potential transitions, insights), and*
4. *The implementation process.*

This phase is the critical communications of all the company has done for the Step 4 analysis. For this phase, the company will want to work with their decision-makers and company planning, policy, sustainability, risk management, strategy, and outreach teams. They will also want to engage their external experts to help with documenting the methodology and effectively, rigorously, and defensibly communicating the results. The experts can also help the company communicate the relevant science to educate readers and ground the methods.

At the end of Phase 7, the company will use the SMARTargets Reporting Template to finalize the documentation for their Step 4 transition risk analysis (Phases 1 through 7). This includes the summary tables of key output indicators, as well as graphics to help communicate the company’s modeling results and insights. Additionally, the company will report the identified enabling conditions for ATs, QTs and corresponding conditions, and the risks and opportunities identified. Finally, the company will indicate their risk management strategies along with their milestones and contingency plans.

The company’s strategy will consist of more than targets. It will also include transition plans as well as strategies for pursuing enabling conditions and managing risks, where the latter might entail research and development plans, collaboration with customers or other sectors, and policy dialogue. Step 4 has a minimum set of required outputs (Table 20 in the methodology document). Additional variables may be added based on company need.

Step 5. Strategy and qualified target alignment with international goals

Step 5 Outputs: International goal alignment assessments of qualified targets and strategies.

In this step, the company will evaluate *qualitative* alignment of their transition strategy with the international goals, as well as *quantitative* alignment of their QTs.

Assessing qualitative alignment of the transition strategy

The company will assess two types of qualitative alignment of their strategy with international goals: (1) alignment with the types of transitions robustly observed in global emissions pathways consistent with the Paris Agreement temperature goals, and (2) alignment with the provisions in the Paris Agreement associated with achieving the temperature goals.

As discussed in the methodology document, the following are robust types of transitions found in all global 1.5°C and 2°C emissions pathways. The following are changes found consistently in well-below 2°C pathways regardless of the model and assumptions:

- Increasing low-carbon technology deployments,
- Increasing reliance on electricity,
- Transitions away from fossil fuels but continued use,
- Use of carbon dioxide removal,
- Improvements in energy conservation and efficiency,
- Differences in regional low-carbon transitions, and
- For any climate goal, substantial uncertainty in the levels, rates of change, and composition (e.g., technologies, energy, activity) of the transition of the global economy.

SF₆ reductions are also a robust characteristic of the global pathways, with reductions in SF₆ producing activity levels and the utilization of SF₆ abatement measures. The transition analysis results can be assessed for consistency with these robust Paris Agreement aligned transition characteristics. As shown in the modeling results, the T&D company strategies will need to rely on both the deployment of low-carbon technologies and increased electrification—particularly under economy-wide net-zero scenarios. The scenarios also indicate a transition away from fossil fuels, though continued use persists in many cases. The set of strategies also includes increasing deployment of low-carbon technologies and energy conservation and efficiency and the use of carbon dioxide removal. They also exhibit significant uncertainty in the transitions and of course, by design, recognize the unique regional transition opportunities.

The assessment, however, is different from that for electricity generation emissions strategies since the utility is needing to consider alternative power markets conditions that are primarily out of their control. The assessment here should therefore focus on the strategy elements the utility can control and influence. For example, in all cases the company strategy is reducing fugitive SF₆ and CO₂ emissions by utilizing fugitive SF₆ and CO₂ line-loss abatement technologies.

Furthermore, the transitions and insights align with Paris Agreement’s provisions recognizing differences in national decarbonization opportunities, multiple societal priorities, transparency, and the value of innovation and cooperation (in this case across sectors via the economy-wide scenarios).

Assessing alignment of the Qualified Targets

The company will also assess quantitative alignment of their QTs through comparison to the relevant global emissions pathway ranges consistent with the Paris Agreement objective of limiting global average temperature to “well-below” 2°C. Table BTD9 shows this comparison. Based on the Step 4 transition risk analysis, the utility identified the following fugitive SF₆ and power sold to end use CO₂ sets of QTs:

3. Fugitive SF₆ QTs #1: 45% reductions by 2050 (with 45% in 2030 and 2040),
4. Fugitive SF₆ QTs #2: 30% reductions by 2050 (with 30% in 2030 and 2040), and
5. CO₂ from power sold to end users QTs: 65% reductions by 2050 (with 36% and 57% reductions in 2040 and 2050).

The conditions associated with the first set of fugitive SF₆ QTs include a growing reference regional power market with a decarbonization transition and Challenging other conditions with high load growth, high gas prices, high generation technology costs, and constraints on new generation and transmission additions. The conditions associated with the second set of fugitive SF₆ QTs include a growing regional power market due to an economy-wide decarbonization transition, More Limited decarbonization options including CDR being unavailable, and emissions constraints on capacity reserves, as well as the Challenging other conditions. The conditions associated with the set of power sold to end users CO₂ QTs include a more slowly growing regional power market due to no regional decarbonization transition and the Challenging other conditions. The QTs were identified by primarily considering the transition implications for affordability. Other factors could also be considered, such as new infrastructure constraints, operational reliability, and the likelihood of future conditions.

Table BTD9. Qualified Target Paris Agreement alignment assessment

Qualified Target set	Key qualifying conditions	GHG	Qualified Target 2050		Well-below 2°C ranges	Within range
Fugitive SF ₆ #1	Growing regional power market due to reference conditions without a decarbonization transition and Challenging other conditions	SF ₆	2030	-45%	13% to -92%	Yes
			2040	-45%	29% to -98%	Yes
			2050	-45%	43% to -98%	Yes
Fugitive SF ₆ #2	Growing regional power market due to an economy-wide decarbonization transition, More Limited decarbonization options including CDR being unavailable and emissions constraints on capacity reserves, as well as the Challenging other conditions	SF ₆	2030	-30%	13% to -92%	Yes
			2040	-30%	29% to -98%	Yes
			2050	-30%	43% to -98%	Yes
Sold power to end users CO ₂	Flat or growing regional gas market due to no regional decarbonization transition in power sector or economy-wide and non-CDR offsets unavailable	Net CO ₂	2030	-36%	10% to -100%	Yes
			2040	-57%	-24% to -121%	Yes
			2050	-65%	-43% to -126%	Yes

Based on the Table BTD9 comparison, this utility would conclude that all their QTs are quantitatively Paris Agreement aligned. As discussed in the methodology document, the high-level insight from the Table BTD9 comparison is that QTs within the ranges are aligned with global futures consistent with limiting warming to well-below 2°C. Furthermore, if all companies have QTs within the range, the sum will also be aligned with well-below 2°C. However, it is critical to keep in mind that this comparison is not conclusive because the global pathways do not capture the transition opportunities and challenges for individual companies, or differences across companies. In addition, the global pathway ranges do not reflect all the sub-global and local transitions found to be aligned with a global temperature. Thus, QTs for some companies may not fall within the global pathway ranges due to their transition challenges. As discussed in the methodology document, the QTs should not be judged negatively based on this comparison. This outcome is simply an indication of the company's challenges. The QTs should be evaluated in terms of their challenges and the strategies for pursuing them and enabling conditions for additional ambition. The QTs represent the highest possible ambition for a company under different conditions while balancing trade-offs and risks that the company would be transparently identifying and communicating. Specifically, the company would communicate what conditions are determining their QTs, as well as how additional reductions could be possible under other conditions.

The company can also visually communicate overall alignment with the Paris Agreement (PA). A graphic like Figure BTD10 can be created and is an effective means to defensibly and quantitatively communicate ambition, as well as alignment of the company targets and transition risk analysis pathways with the Paris Agreement temperature goal. The company will want to include a narrative with Figure BTD10 discussing the information shown and describing SMARTargets' comprehensive Paris Agreement alignment—quantitative, qualitative, and in the company-specific evaluation of two reduction types (ATs and QTs) that recognizes differences in transition opportunities, challenges, risks, and enabling conditions.

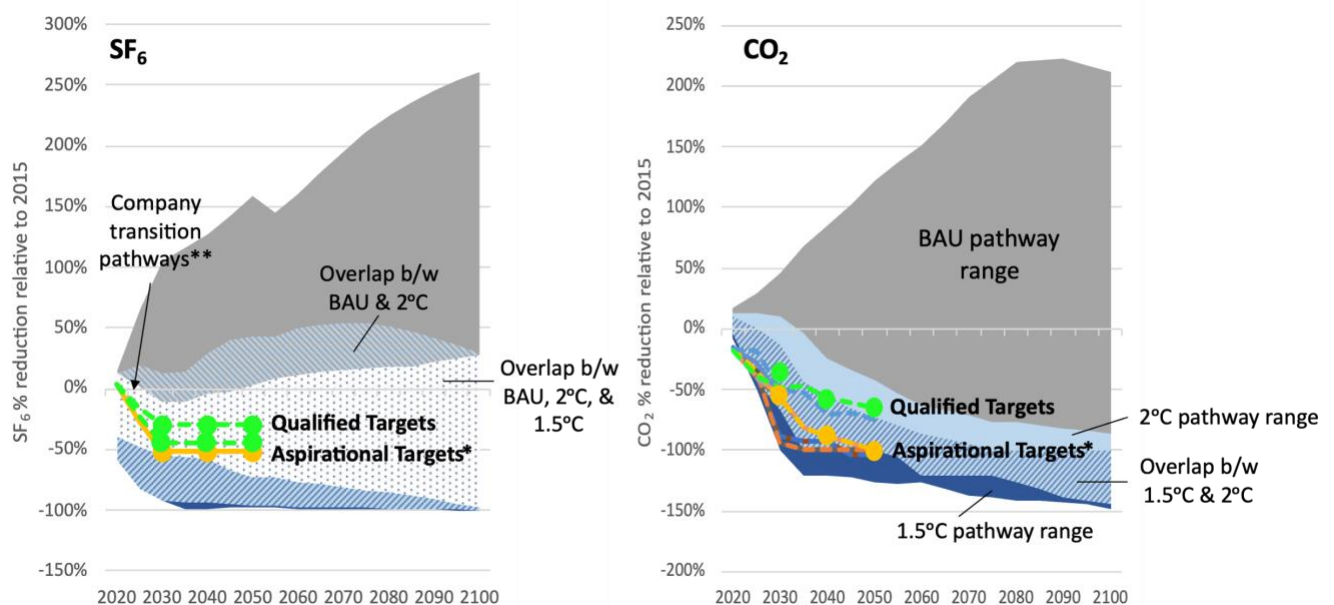


Figure BTD10. Alignment of illustrative company fugitive gas CH₄ and gas consumption CO₂ Aspirational and Qualified Targets with the global emissions pathways consistent with the Paris Agreement temperature goals

Source: EPRI

Figure notes: Aspirational Targets denoted with yellow dots with solid line transition pathways. Qualified Targets denoted with green dots with dashed line transition pathways. Developed from EPRI (forthcoming) analysis of the IPCC's Sixth Assessment Report, IEA Net Zero by 2050, and other recent global emissions pathways, and the EPRI illustrative US-REGEN analysis completed for this example. See EPRI (forthcoming) and EPRI (2020 and 2018) for detailed assessments of recent and previous global emissions pathway modeling and results, including discussion of global pathway limitations and the importance of using full ranges due to the nature of the IPCC data. Solid and dotted lines indicate AT and QT transition pathways respectively.

* Enabling conditions may be needed to achieve the Aspirational Targets. See the company transition risk analysis and narrative that identifies the enabling conditions and Qualified Targets reductions and their qualifying conditions.

** Shown are the CH₄ and CO₂ transitions after the additional abatement required for achieving the Aspirational and Qualified Targets identified from the Step 4 transition risk analysis.

Step 6. Documentation and communication

Step 6 Output: SMARTargets documentation.

In this step, the utility will document and communicate their SMARTargets implementation using the SMARTargets Reporting Template. This includes documenting implementation choices with justification, transition analysis insights, targets, strategy, and milestones. Through the template, the following information will be assembled:

- General company information and stakeholder engagement,
- GHG Inventories and base year,
- Practical issues and climate target groupings,
- Company transition risk analysis of opportunities and risks,
- Alignment assessment,
- Documentation and communication of targets, strategies and indicators, and
- Implementation and monitoring.

The set of information represents a clear, comprehensive, and transparent package of information about the process and the outcomes. Overall, in applying the methodology, the utility will produce the following standardized and comparable results that reflect their implementation and climate strategy:

- e. Paris Agreement-aligned targets and enabling conditions, including Aspirational Targets (AT) and Qualified Targets (QT) and their associated conditions,
- f. Insights into potential low-carbon transitions,
- g. Assessment of risks, risk management strategies, and overall transition strategy, and
- h. Documentation of methodology implementation, including:
 - GHG inventory by required emissions category,
 - Responses to practical considerations and target-setting decisions for each category,
 - Transition risk analysis components:
 - Modeling approach
 - Reference conditions and key uncertainties
 - Core scenario definitions and specifications
 - Criteria for identifying risks and enabling conditions

In addition, the company is encouraged to holistically communicate their strategy. This goes beyond emissions targets and includes leadership strategies to help create the enabling conditions for achieving greater emissions reductions and economy-wide decarbonization, such as research and development (R&D), educational outreach (stakeholder and policy), and collaboration and coordination with customers

1 and supply chain partners. For this illustrative utility, the analysis has identified that risk management is
2 important given the significant uncertainty and lack of control over the size of the power market and the
3 generation resources. Among other things, for fugitive SF₆, this could include research and development
4 that lowers the cost and increases the availability of technologies for reducing the fugitive SF₆ emissions,
5 such as SF₆-free gas insulation alternatives. For their largest source of emissions, CO₂ associated with sold
6 power to end users, abatement cost risk management might include encouraging the decarbonization of
7 power and the availability of decarbonization options. For all sources, abatement cost risk management
8 might include pursuing the Facilitating conditions, such as generation technology cost improvements and
9 reducing barriers to new generation and transmission.

10
11 Finally, the company would also want to consider communicating on the SMARTargets Methodology
12 itself, including its scientific foundations. This can involve referencing the publicly available methodology,
13 the SMARTargets Scientific Foundations, and other materials and emphasizing how the approach is
14 science-based and aligned with the Paris Agreement (see Justification for the Methodology section).

15 **Step 7. Validation and Verification**

16 **Step 7 Outputs:** Validated SMARTargets and verified progress.

17
18 In this step, the utility will validate their SMARTargets and verify progress. After completing the
19 SMARTargets Reporting Template in Step 6, the utility will be able to initiate validation activities.
20 Validation assesses whether the methodology has been properly implemented and whether the target
21 and strategy—by nature forward-looking statements—are supported by sound assumptions, data, and
22 methods. The primary input for validation is the SMARTargets Reporting Template.

23
24 The utility will begin with internal validation, leveraging internal audit processes aligned with recognized
25 standards. This step ensures the methodology has been correctly applied and that the resulting targets
26 and strategies are scientifically grounded and aligned with the Paris Agreement. Internal validation also
27 builds confidence by thoroughly documenting the rationale and process behind the targets—information
28 that is essential for both third-party validation and external communications.

29
30 Internal validation is all that is possible in the near-term. Accredited, independent third-party validation
31 services for corporate GHG targets do not currently exist. Third-party validation is recommended once it
32 becomes available. It provides an independent, authoritative assessment of conformity with the
33 SMARTargets Methodology and validation criteria.

34
35 Following validation, the utility will communicate the results to the public, including regulators, investors,
36 and other interested stakeholders.

37
38 In addition to validating, the utility is required to verify progress periodically. The utility will evaluate
39 actual emissions reductions against its targets using the most recent GHG emissions inventory. The same
40 third-party provider that verifies the GHG inventory could also perform this progress verification, thereby
41 ensuring consistency and credibility with reporting. This verification relies on GHG inventories, which are
42 based on observable data and are therefore subject to assurance-level assessments.

Step 8. Monitoring and adjusting

Step 8 Outputs: Periodic milestone assessment and, as needed, strategy adjustment and/or SMARTargets refresh.

Under this step, the company will annually monitor their milestones and adjust their strategy as needed. The utility will need to monitor conditions with respect to their milestones to determine if strategy adjustments are needed and/or if updated SMARTargets analysis, targets, and strategies are needed.

The transition risk analysis (Step 4) provides milestone and contingency insights as well as insights regarding transition opportunities and risks. The company should articulate meaningful and observable milestones, and potential responses, based on their analysis, with the milestones clearly communicated in the Reporting Template. For instance, the Step 4 results above suggest the need to evaluate which future is emerging. If, for example, Facilitating conditions are emerging lowering generation technology costs, barriers to additions, and NIMBY sentiments, and/or offsets are available, the utility could pursue additional emissions reduction ambition beyond their QTs. Other key milestones identified include whether a regional decarbonization transition (power sector or economy-wide) is occurring, the availability of CDR, electrification trends, and the costs and availability of fugitive SF₆ abatement technologies and strategies for reducing T&D line losses. In particular, tracking the emergence of sector-specific or economy-wide decarbonization will be important because of their impact on the size of the electricity market and the mix of generating technologies. The results above highlighted that Facilitating conditions with decarbonization transitions in the power sector or economy overall would enable the utility to achieve the CO₂ ATs. For SF₆, the ATs would be more attainable with Facilitating conditions and either no decarbonization transition or an electric sector decarbonization with More Limited options. All these factors shape the feasibility and timing for T&D emissions reductions. Tracking these trends informs the utility's evaluation and possible adjustment of its T&D targets.

Illustrative results for gas utility emissions targets

This example illustrates the derivation of SMARTargets for gas utility emissions for a hypothetical company that purchases natural gas from producers and delivers the gas to consumers. The primary categories of GHG emissions for this utility are the following:

1. Direct fugitive CH₄ emissions from gas distribution (scope 1),
2. Upstream fugitive CH₄ emissions from gas production, processing, and transmission (scope 3), and
3. Downstream CO₂ emissions from end-use gas consumption (scope 3).

All of the gas utility's emissions categories are a function of the size and composition of the overall gas market. The gas market is determined by many factors that are generally not controlled by a gas utility. As such, it is a key uncertainty for the utility and essential to evaluate.

The illustrative example is based on a U.S. Midwestern region and the company sits within the region and is interested in understanding how the regional gas market and economy might evolve with decarbonization by 2050 and what might be the implications and risks. Using US-REGEN and fugitive CH₄ abatement cost data, we can constrain emissions and evaluate alternative potential low-emissions transitions for the regional gas market, the three categories of GHG emissions, and GHG abatement opportunities.

Below, we describe how this gas utility would apply each step of the SMARTargets Methodology.

Step 1: GHG inventories and base year

Step 1 Outputs: Verified GHG inventory and emissions reductions base year.

The first step is for the company to assemble their GHG inventory and select a base year. The company will need GHG emissions accounts for each of the categories of emissions relevant to their business. The company will also need to decide on their emissions reduction base year and apply it consistently. Note that the company will need to have the inventories verified.

For this example, Table BG1 summarizes the emissions for our illustrative utility. The primary source of emissions is downstream gas consumption CO₂, however, fugitive direct and indirect CH₄ emissions are also noteworthy. The utility could have other emission sources but, for this example, we assume they represent only a small fraction of the overall inventory and are immaterial.

The emissions trends for each category are shown in Figure BG1. As illustrated, CH₄ emissions have shown a steady decline; however, since 2015, emissions have increased slightly and leveled off. In contrast, CO₂ emissions have been fairly flat with a slight upward trend and decrease in the last few years. An analysis of the emissions drivers reveals that these trends are primarily driven by steady gas consumption, efficiency improvements, and electrification with shifts away from gas.

Given the information available, we assume the utility decides to select 2015 as its base year. This decision is based on considering the accuracy of their inventories, the inventory years verified, and choosing a year that facilitates communications regarding the utility's emissions trends.

Table BG1. GHG inventory for key categories in gas utility illustrative example

Source: EPRI with data from EPA (2024), IEA (2025) and illustrative gas utility GHG inventories.

Key emissions categories	2015 (base year)	2021 (most recent)
	MMtonCO _{2e}	
Direct fugitive CH ₄ emissions from gas distribution	0.3	0.3
Upstream fugitive CH ₄ emissions from gas production, processing, and transmission	0.3	0.3
Downstream CO ₂ emissions from end-use gas consumption	4.7	3.6

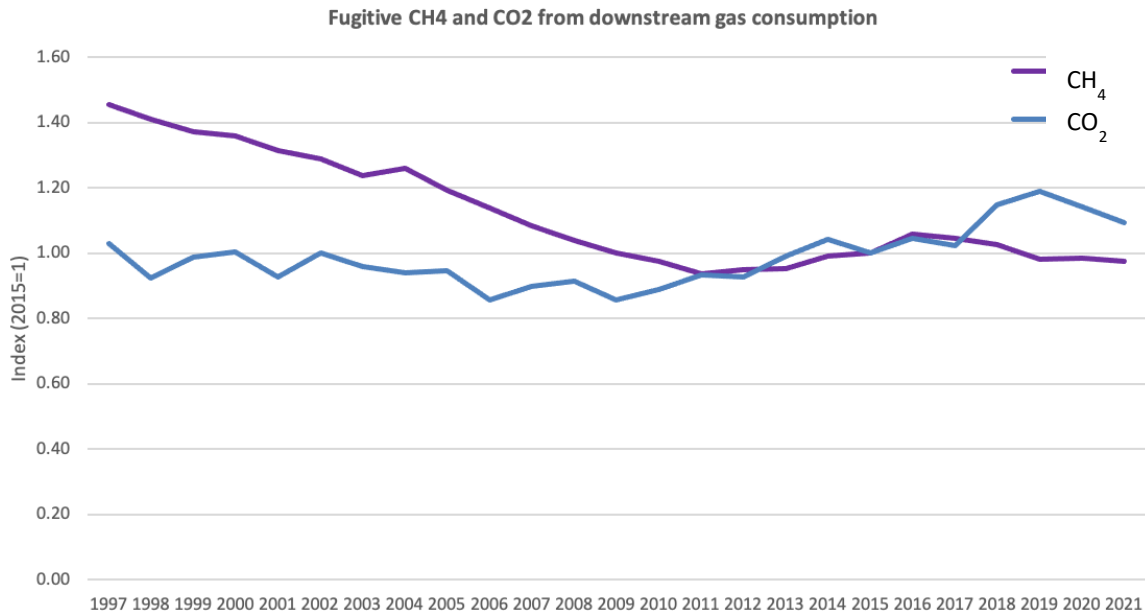


Figure BG1. Emissions Trends for key categories in gas utility illustrative example

Step 2. Practical issues and climate target groupings

Step 2 Outputs: Decisions on practical issues, including emissions categories covered (by regulation or company targets), the categories for which targets are being set, and how these categories are grouped for target evaluation.

For this step, our illustrative gas utility works through the company target setting practical issues, as well as identifies their target groupings. Table BG2 presents example responses to the set of practical issues questions for all three emissions categories, and below we discuss the implications. This step helps companies assess practical considerations that may influence their ability to set and achieve targets. The company's responses also inform their evaluation of targets (Step 4).

1 Table BG2. Illustrative practical issues responses for the primary gas utility emissions categories

Company Target Setting Practical Considerations question	Response for gas distribution fugitive CH ₄ (Scope 1 Direct Emissions from Fugitive Sources)	Response for gas production, processing, and transmission fugitive CH ₄ (Scope 3 Category 3 Fuel- and energy-related activities not in scopes 1 and 2)	Response for gas combustion CO ₂ (Scope 3 Category 11 Use of sold products)
Is the emissions category adequately estimated and reported?	Yes, the emissions can be adequately characterized	There is uncertainty about the emissions due to uncertainty regarding upstream activity, operations, and technology practices	Yes, the emissions can be adequately characterized
Are the emissions material to the company's overall GHG inventory? (e.g., above 5% of total emissions or a threshold defined by the company)	Yes, the emissions from this source category are greater than 5% of emissions	Yes, the emissions from this source category are greater than 5% of emissions	Yes, the emissions from this source category are greater than 5% of emissions
Are the category's emissions regulated by a Paris Agreement aligned policy?	No, the emissions from this source category are not currently regulated	Yes, the emissions from this source category are currently regulated	Yes, the emissions from this source category are currently partly regulated
Does another company in the value chain already set Paris Agreement-aligned targets for this source? (applicable only to indirect emission sources)	n/a, these are direct emissions.	No, the source does not currently have a Paris Agreement-aligned target separate from emissions reduction compliance requirements	No, the source does not currently have a Paris Agreement-aligned target separate from emissions reduction compliance requirements
Does the company have control or influence over the emissions?	Yes, the utility has control over these emissions	Limited, these emissions come from the assets and operations of the provider companies	Limited, these emissions are produced by consumers based on their preferences and choices and available technologies

2
3 Based on the responses above, the company might want to deliberate on whether to set a target for each
4 of the categories. Upstream fugitive CH₄ emissions are difficult to robustly quantify and may be regulated,
5 such as by the U.S. Environmental Protection Agency. The company may still choose to evaluate and
6 potentially set targets, but some of these issues will complicate the company's efforts to pursue the
7 target, as well as society's interest in cost-effective decarbonization. For example, the lack of control of
8 upstream fugitive CH₄ and downstream combustion CO₂ means that there is more uncertainty and risk for

the company in achieving targets for these sources. More specifically, the company not only does not control the emitting technologies and activities, but they do not control the size and composition of the gas market, which as discussed below is the primary uncertainty the company needs to evaluate. Note, for downstream combustion CO₂, customer initiatives could be deployed, but their effectiveness may be limited.

Overall, in this example, the company has legitimate practical reasons for not setting targets for upstream fugitive CH₄ emissions. Recall that, for each emissions category, the company decides whether to:

1. Set a target (using the subsequent SMARTargets steps),
2. Not set a target because the emissions are already covered by a Paris Agreement aligned policy or another company's Paris Agreement aligned targets,
3. Not set a target with justification based on practical considerations that currently preclude target setting, or
4. Not set a target because the category is not relevant to their business.

For the sake of this illustration, we assume that the company chooses to set targets for all three categories despite the practical issues identified and they will therefore undertake subsequent steps, including the Step 4 analysis to evaluate the targets, transition opportunities and risks, and enabling conditions. However, the company should keep these issues in mind as it considers its strategies for achieving targets, including contingency plans for different possible future conditions.

Another utility might have different responses to some of the questions in Table BG2 or reach a different conclusion based on the responses in the table. For instance, a different utility might conclude that existing regulations are resulting in Paris Agreement aligned reductions in fugitive CH₄ emissions and it is therefore practical and cost-effective to focus on compliance and not set targets.

In this step, the company also needs to decide on its target groupings. For this example, we assume the company pursues separate CH₄ and net CO₂ targets for each of the three emissions categories. The company's overall target setting and target grouping decisions are documented in Table BG3.

Table BG3. Emissions category targets

Table note: Emissions categories are those from Table B2. * Emissions not relevant to business or not material to inventory.

Emissions category	GHG total (MtCO ₂ e or NA if not relevant to business)	Currently covered				To be covered by future Company SMARTargets (MtCO ₂ e)	Not Covered (MtCO ₂ e)	Justification (and, as relevant, plans for not covered emissions and future targets)
		By Our Current Company SMARTargets (MtCO ₂ e)	SMARTarget type (indicate if target for category, GHG, or CO ₂ e)	By Paris Agreement Aligned Regulation (MtCO ₂ e)	By Another Company's Paris Agreement Aligned Targets (MtCO ₂ e)			
Scope 1. Direct Emissions from Stationary Combustion	0.2							Not material*
Scope 1. Direct Emissions from Mobile Combustion	0.0 (< 0.1)							Not material*
Scope 1. Direct Emissions from Process Sources	n/a							n/a
Scope 1. Direct Emissions from Fugitive Sources	0.3	0.3	CH ₄					Fugitive methane emissions from gas distribution operations are material
Scope 2. Indirect Emissions from Purchased/Acquired Electricity	n/a							n/a
Scope 2. Indirect Emissions from Purchased/Acquired Steam	n/a							n/a
Scope 2. Indirect Emissions from Purchased/Acquired Heating	n/a							n/a
Scope 2. Indirect Emissions from Purchased/Acquired Cooling	n/a							n/a
Scope 3. Fuel- and energy-related activities (not included in scope 1 or 2)	0.3	0.3	CH ₄					Fugitive methane emissions from upstream gas production are material
Scope 3. Use of sold products	3.6	3.6	CO ₂					CO ₂ emissions from use of natural gas by end user are material

Step 3. Aspirational targets aligned with international goals

Step 3 Outputs: Aspirational targets that will be evaluated in the Step 4 transition risk analysis.

For this step, the utility will select generic Aspirational Targets (ATs) aligned with the international goals for their CH₄ and net CO₂ targets. The utility identifies intermediate and 2050 ATs using Table BG4, which shows the CH₄ and net CO₂ ATs from Table 6 of the methodology document. The utility must select a 2030 or 2035 intermediate AT, as well as a 2050 AT. They are also welcome to select additional pre-2050 intermediate targets using the table. For this example, we assume the utility chooses to select 2030 and 2040 intermediate ATs and therefore their set of net CO₂ ATs are -56%, -88%, and net-zero (-100%) from 2015 for 2030, 2040, and 2050 respectively; and, their set of CH₄ ATs for both fugitive categories are -37%, -41%, and -47% from 2015 for 2030, 2040, and 2050 respectively.

Table BG4. Generic Aspirational Targets (% reduction from 2015)

	CH ₄	Net CO ₂
2030	-37%	-56%
2035	-39%	-82%
2040	-41%	-88%
2045	-45%	-94%
2050	-47%	-100%

Step 4. Company transition risk analysis of opportunities and risks

Step 4 Outputs: Company regional transition opportunities and risks, evaluation of aspirational and qualified targets and their enabling conditions, and transition strategies (low-carbon & risk management).

Given that the utility has decided to evaluate and pursue targets (Step 2), they will need to undertake transition risk analysis to identify their opportunities, risks, and risk management strategies for pursuing the Step 3 ATs and identifying qualified targets (QTs) and their associated conditions. The utility works through the seven phases associated with the transition risk analysis. The example analysis below informs all three of the company's target types.

Phase 1: Define reference conditions and itemize uncertainties

- Phase inputs: Previous company planning, strategy, analysis, and risk management experience
- Phase outputs: Scenario analysis reference conditions and list of uncertain factors to consider in scenario design
- Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as possibly external experts on scenario analysis and modeling
- Documentation: SMARTargets template summarizing reference conditions and uncertain transition factors for scenario design consideration

For this phase, the illustrative company works with their planning, policy, sustainability, risk management, strategy, and outreach staff, as well as any external experts on scenario analysis and modeling with which

they choose to collaborate, to define their scenario analysis reference conditions and the uncertain factors that they wish to consider in their scenario design in Phase 2.

The key uncertainty for the gas utility CH₄ and CO₂ emissions categories is the size and composition of the future regional gas market. A gas market twice the size of today in 2050 will have twice the level of emissions, and a gas market half the size of today in 2050 will have half the level of emissions. Similarly, greater use of low-carbon gas alternatives to natural gas, such as renewable natural gas and synthetic gas made from CO₂, could lower the CO₂ emissions associated with gas consumption. Thus, the company will want to discuss potential reference conditions and identify uncertain factors that can influence the size and composition of the gas market.

Unsurprisingly, many of the conditions and uncertain factors relevant to the electricity generating utility's potential transitions in the previous example are also relevant for a gas utility. For example, for the reference conditions, our hypothetical company develops lists for announced energy infrastructure retirements and new builds that will be implemented as constraints in the modeling analysis. In addition, the company will also want to include local and federal policy drivers that should be a part of every transition future they evaluate.

The company staff, and any experts involved will also develop a list of uncertain factors that they believe are or could be important and that they want to evaluate in some way. In this case, we are using the same uncertain factors that were identified by the electricity generating utility since they are also factors relevant to power and economy-wide gas use transitions. We have, however, also added two additional uncertainties regarding gas system fugitive CH₄ abatement technology cost and performance improvement uncertainty and low-carbon gas cost improvement uncertainty:

- Electricity supply decarbonization options,
- Electricity supply technology cost and performance improvements,
- Future electricity demand (load),
- Low-carbon generation technology development and commercialization,
- Low-carbon generation technology permitting,
- Supply chain constraints related to low-carbon generation technologies,
- Not in my backyard (NIMBY) issues,
- Resource procurement,
- Support for new transmission infrastructure investments,
- New transmission infrastructure costs,
- New transmission siting and permitting,
- Fuel availability,
- Fuel pipeline capacity/augmentation,
- End-use technology cost and performance improvements,
- Gas system fugitive CH₄ abatement technology cost and performance improvements, and
- Low-carbon gas cost improvement.

Note that the SMARTargets Methodology scenario design for gas utility emissions already accounts for uncertainty about decarbonization transitions—reference (without decarbonization ambition), power sector only, and economy-wide. Like the electricity generating utility, these are relevant to the gas utility as significant factors influencing potential gas market transitions. At the end of Phase 1, the utility will document their reference conditions and itemize the identified uncertain factors in the SMARTargets Reporting Template.

Phase 2: Create core scenario design – define plausible extreme alternative future conditions

- *Phase inputs: Phase 1 scenario analysis reference conditions and list of uncertain factors to consider in scenario design.*
- *Phase outputs: The company's core scenario design for the required SMARTargets scenarios.*
- *Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as possibly external experts on scenario analysis and modeling.*
- *Documentation after iterations: SMARTargets Reporting Template entries summarizing the core scenario design.*

For this phase, the company continues working with the same team as in Phase 1 to define their core scenario design for the required SMARTargets scenarios. Table BG5 presents the required core scenarios for gas utility emissions from the methodology. For evaluating the ATs for gas utility emissions, the required scenarios are the net-zero scenarios for electricity generation CO₂ targets and the reference scenarios. The reference scenarios help the gas utility evaluate the gas market and fugitive CH₄ and gas combustion CO₂ targets when electricity or economy-wide decarbonization are not pursued. This type of future is a part of the plausible transition space for a gas utility and therefore should be evaluated. The company will then want to evaluate a range of target levels for CH₄ and CO₂ for identifying their QTs after they review the results for the ATs and reference conditions.

To implement the Table BG5 scenarios, the company needs to define the conditions—Fuller/More Limited decarbonization options and Facilitating/Challenging other conditions. Recall that the conditions should be intentionally more extreme, but plausible. In this example, we use the same condition definitions that were used for evaluating electricity generation targets. See the electricity generation target example for discussion of the three intermediate steps associated with grouping and defining the Facilitating and Challenging non-climate-policy conditions.

The outcome of the second phase, combining uncertainty categories into sets of conditions and defining the relative conditions, is what is shown in Table BG6. Table BG6 is identical to Table BE6 that was used for the electricity generation targets example. The set of uncertainties considered in both the Facilitating and Challenging conditions includes uncertainty regarding electricity generation cost improvements, electricity capacity additions, electricity transmission additions, fossil fuel prices, and electric technology cost improvements. Note that, Table BG6 does not include fugitive CH₄ abatement technology or low-carbon gas cost and performance uncertainties. These are relevant uncertainties, however, current estimates of the cost of gas system fugitive CH₄ abatement opportunities and low-carbon gas costs do not typically provide quantitative uncertainty estimates. Thus, this uncertainty is not being considered in this example analysis due to the absence of data; but, these uncertainties could be incorporated in the future.

With the scenario conditions defined, the company is ready for Phase 3 and quantification of the alternative conditions. At the end of Phase 2, the company should document their definitions of Fuller/More Limited and Facilitating/Challenging using the SMARTargets Reporting Template.

1 Table BG5. Required scenarios for evaluating targets for gas utility emissions

Target pathway type being evaluated	2050 targets for pathways	Electric sector transition	Economy-wide transition to net-zero in 2050	Decarbonization options	Other conditions
Aspirational Targets (CH ₄ & net CO ₂ ATs and QTs > ATs)	CH ₄ 47% & net CO ₂ 100%	Reference (without CO ₂ constraint)	No	N/A	Facilitating
		Reference (without CO ₂ constraint)	No	N/A	Challenging
		Transition to net-zero CO ₂ in 2050	No	Fuller	Facilitating
		Transition to net-zero CO ₂ in 2050	No	More Limited	Challenging
		Transition to net-zero CO ₂ in 2050	Yes	Fuller	Facilitating
		Transition to net-zero CO ₂ in 2050	Yes	More Limited	Challenging
Qualified Targets (CH ₄ & net CO ₂ QTs < ATs)	CH ₄ A, B, C% & net CO ₂ X, Y, Z%	Reference (without CO ₂ constraint)	No	N/A	Facilitating
		Reference (without CO ₂ constraint)	No	N/A	Challenging
		Transition to net-zero CO ₂ in 2050	No	Fuller	Facilitating
		Transition to net-zero CO ₂ in 2050	No	More Limited	Challenging
		Transition to net-zero CO ₂ in 2050	Yes	Fuller	Facilitating
		Transition to net-zero CO ₂ in 2050	Yes	More Limited	Challenging

2

3

4 Table BG6. Illustrative Fuller/More Limited and Facilitating/Challenging decarbonization condition definitions

Illustrative FULLER decarbonization set

Renewables (wind, solar, bio, hydro)
Nuclear (extensions)
Advanced nuclear (additions)
Fossil
Fossil w/CCS
CDR (biopower w/ CCS & direct air capture (DAC))
Storage
Hydrogen
Biomass carbon neutrality
Other renewable fuels
Low-carbon power imports
Fossil capacity reserves permitted (within emissions constraint)
Demand conservation and energy efficiency

Illustrative FACILITATING other conditions

Reference electricity load growth
Faster electricity generation cost improvements,
Economic electricity capacity additions,
Economic electricity transmission additions,
Lower fossil fuel prices,
Faster electric technology cost improvements

Illustrative MORE LIMITED decarbonization set

Renewables (wind, solar, bio, hydro)
Nuclear (extensions only)
Storage
Electrolytic Hydrogen only
Fossil capacity reserve eligibility declines to zero in 2050
Demand conservation and energy efficiency

Illustrative CHALLENGING other conditions

Faster electricity load growth
Slower electricity generation cost improvements,
Constrained electricity capacity additions,
Constrained electricity transmission additions,
Higher fossil fuel prices,
Slower electric technology cost improvements

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Phase 3: Implement scenario design – specify assumptions for scenario modeling

- *Phase inputs: The company's Phase 2 core scenario design for the required SMARTargets scenarios.*
- *Phase outputs: Specification of core scenario design for the company's modeling framework.*
- *Who should be involved: Staff related to planning, sustainability, policy, and strategy, as well as external experts on scenario analysis, modeling, and alternative assumptions.*
- *Stakeholder engagement: This is a good time to seek external stakeholder feedback.*
- *Documentation after iterations: SMARTargets Reporting Template entries summarizing the core scenario design specification.*

For this phase, the company continues working with the same team as in Phases 1 and 2 to specify the core scenario design for their modeling framework. Phase 2 provides the company with everything they need conceptually and qualitatively in terms of the scenarios they want to run. Running the scenarios, however, requires quantification of the scenario design. This includes specifying decarbonization technology cost and performance assumptions, as well as what exactly is meant by “faster” and “slower” cost improvements, and “constrained” capacity and transmission additions. Since we are using the same condition definitions as used for the electricity generation target example, we also use the same specifications (Tables BG7a and BG7b are the same as Tables BE7a and BE7b).

Tables BG7a and BG7b present an illustrative specification for each of the assumptions associated with the Fuller/More Limited and Facilitating/Challenging conditions. Remember that the specification definitions are intentionally extreme, but plausible, alternative conditions. They are also grounded with justification provided for the specifications.

The utility will also need to define the emissions constraint pathways they will be imposing on the model. These constraints will constrain the model to producing no more than the emissions reductions specified (though the model could produce emissions below the constraints).

After completing Phase 3 is a good time for external stakeholder feedback on the scenario design and specifications. It is an opportunity to discuss setting SMARTargets and the planned transition risk analysis and preliminary future conditions the company is considering. At the end of Phase 3, the company should document their specifications for their Fuller and More Limited decarbonization options, their Facilitating and Challenging conditions, and their emissions constraints in the SMARTargets Reporting Template.

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3 Table BG7a. Illustrative summary of energy technology assumptions

Decarbonization technology cost and performance	Comment/description	Reference
Renewables (wind, solar, bio, hydro), nuclear, advanced nuclear, coal, coal w/ CCS, gas, gas w/ CCS, CDR (biopower w/ CCS, DAC), storage, hydrogen	Engineering-based cost and performance specifications with gradual improvement over time	EPRI (2022b)
Biomass carbon neutrality	Carbon neutral assumption based on analysis of net land use and GHG changes associated with increasing biomass supplies	Blanford et al (2022)
Other renewable fuels	Renewable liquid and gas fuels, including renewable gasoline, diesel, and jet fuel, renewable natural gas, and synthetic natural gas produce with renewable energy	Blanford et al (2022)
Low-carbon power imports	Low-carbon electricity can be exported to other regions via intra-regional transmission	EPRI (2023)
Fossil capacity reserves permitted (within emissions constraint)	Fossil generation capacity can be used to meet capacity reserve requirements but declining emissions constraints over time apply to any generation from that capacity	EPRI (2022b)
Demand conservation and energy efficiency	End-use sectors can reduce emissions through technology and fuel substitution that increases efficiency, as well as reductions in overall use	Blanford et al (2022)

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Table BG7b. Illustrative specifications for Facilitating and Challenging other condition assumptions

Other conditions	Facilitating	Challenging
Electricity load growth	Reference = load growth due to reference economic and population growth assumptions and electrification due to electric technology relative cost improvements	Faster = reference load growth conditions plus additional data center load growth based on recent trends resulting in 12% greater total load by 2030 (EPRI, 2024)
Electricity generation cost improvements	Faster = default cost projections and reference learning curve for battery cost improvements over time	Slower = higher cost projections by technology and slower learning curve for battery cost improvements over time
Electricity capacity additions	Economic = allows for all economically viable electric capacity to be built	Constrained = limits the building of economically viable electric capacity to historical build rates
Electricity transmission additions	Economic = allows for all economically viable interregional transmission to be built	Constrained = limits the building of economically viable interregional transmission based on historical transmission build rates
Fossil fuel prices*	Lower = No additional supply costs for fossil fuel production beyond the equilibrium cost determined by the energy economy model's balance of supply and demand for each fuel	Higher = Additional supply costs added to fossil fuel production modeling low resource availability or pipeline expansion
Electric technology cost improvements	Faster = Default cost reductions in EV & heat pump components, faster EV adoption reflective of less range anxiety and greater availability of new electric technologies	Slower = Higher component costs for EV & heat pumps, slower EV adoption representative of more range anxiety and less availability of new electric technologies

* The fossil fuel price assumptions in the table reflect the US-REGEN modeling structure. Other economy-wide frameworks might have fixed assumed (i.e., exogenous) energy prices. For instance, they might be based on lower/higher U.S. Department of Energy Annual Energy Outlook fuel price projections.

Phase 4: Identify potential transitions and target implications

- Phase inputs: Phase 3 specification of core scenario design for implementation in the company's modeling framework.
- Phase outputs: Preliminary transition analysis pathways and insights.
- Who should be involved: Staff and external experts running the model and processing outputs.
- Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.

For this phase, the company's staff and external experts running the model and processing outputs will work together to develop preliminary transition analysis pathway results and insights. The team will be running the model with the scenario specification implementation developed in Phase 3, and they will have to debug and likely revise the scenario specification implementation as they attempt to run each of the scenarios in the design. They will also want to review the results for non-intuitive, or otherwise

1 problematic, outcomes that could be an artifact of an incorrect scenario specification or implementation.
2 The team would want to revise and rerun scenarios in these cases as well.

3 In addition to running the scenarios, the team will develop preliminary graphics—figures and tables—and
4 identify preliminary insights for review. In particular, the team will want to evaluate differences and
5 similarities in transition results between scenarios. The differences between the scenarios are the most
6 meaningful insights, not the specific values from individual scenarios, as you will learn something about
7 the direction and order of magnitude of implications for the different conditions. For instance, gas utilities
8 would be interested in the alternative potential transitions for the gas market size and composition,
9 emissions, and the abatement costs for each emissions category. The modeling provides information
10 regarding the alternative potential transitions, trade-offs, uncertainty, risks, enabling conditions, robust
11 strategies, contingencies, and more. Below we present sample results for the company's scenario design.
12 For this example, we are evaluating potential market transitions for a company in the midwestern U.S.
13 These results represent potential alternative market and operational conditions for the company's system
14 and assets.

15 The overall approach is, for each emissions category, to first estimate the future potential gas markets
16 and the associated emissions under the different scenario conditions. The next step is to evaluate target
17 setting. For both fugitive CH₄ emissions categories, we evaluate targets by applying marginal abatement
18 cost curves to estimate costs for a range of emissions reduction levels for a given gas market. For gas
19 consumption CO₂ emissions, we evaluate targets using the scenario modeling end-use decarbonization
20 outcomes (emissions reductions and portfolios) from which costs can be estimated using the resulting
21 CO₂ prices.

22 Figure BG2 presents the model estimated total gas consumption transitions for all the required scenarios.
23 Gas consumption includes gas used by the power sector, as well as the rest of the economy, including
24 residential and industrial use. We observe the possibility of increasing or decreasing gas consumption,
25 with natural gas still being consumed across the regional economy in 2050 in all the transitions. In 2050,
26 we find the possibility of a regional gas market that is approximately 70% smaller than today or 80% larger,
27 with the transitions from today rising, peaking, flat, or falling. We also find only a modest potential role
28 for low-carbon gas in this region. The smallest gas market by 2050 occurs in the economy-wide
29 decarbonization scenarios, and the largest occurs in the reference scenarios without power sector or
30 economy-wide decarbonization. We also find that the Facilitating conditions, with assumed lower gas
31 prices, result in a larger gas market compared to the comparable Challenging future. Finally, the Fuller
32 versus More Limited decarbonization conditions have their greatest impact when there is an economy-
33 wide decarbonization policy. In this case, the absence of carbon dioxide removal in the More Limited
34 context is contributing to a larger reduction in the size of the future gas market. The key uncertainty for
35 the gas market is whether there is an economy-wide, an electric sector, or no decarbonization transition.

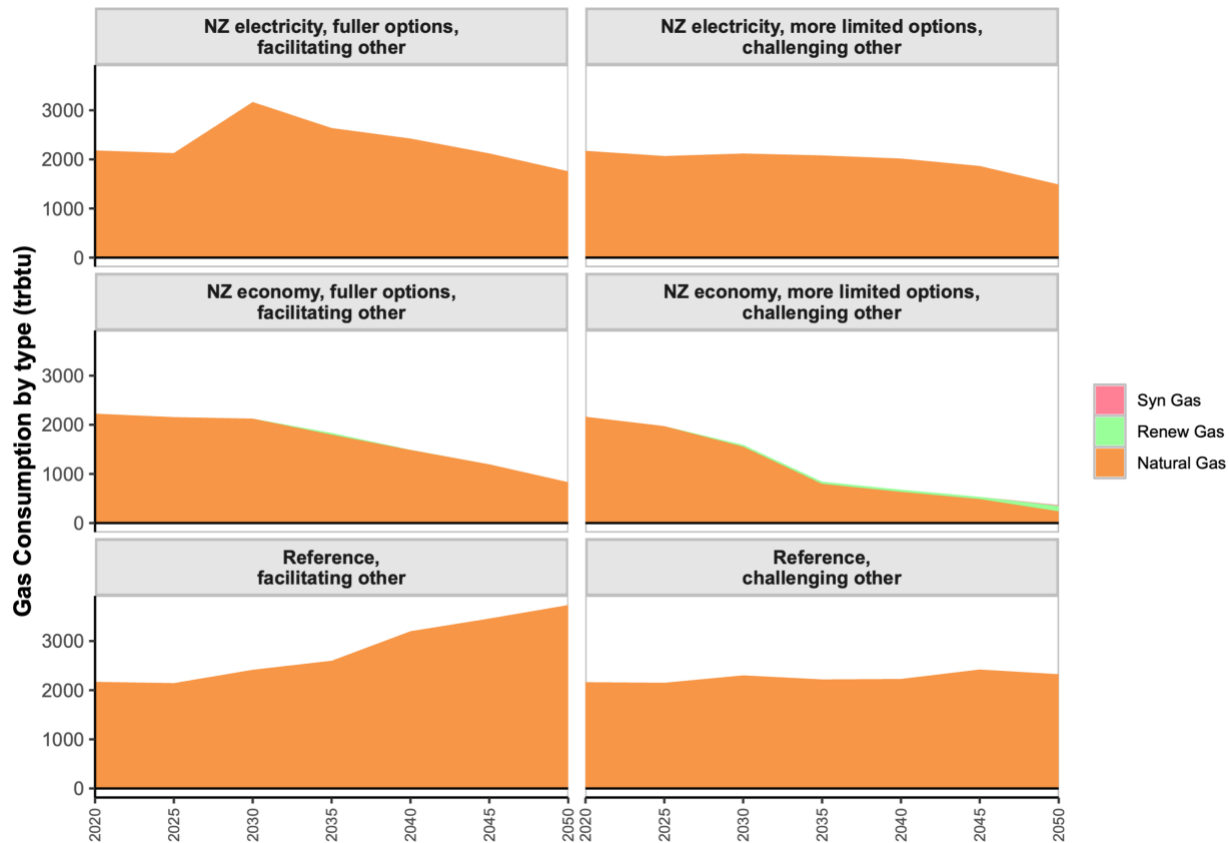
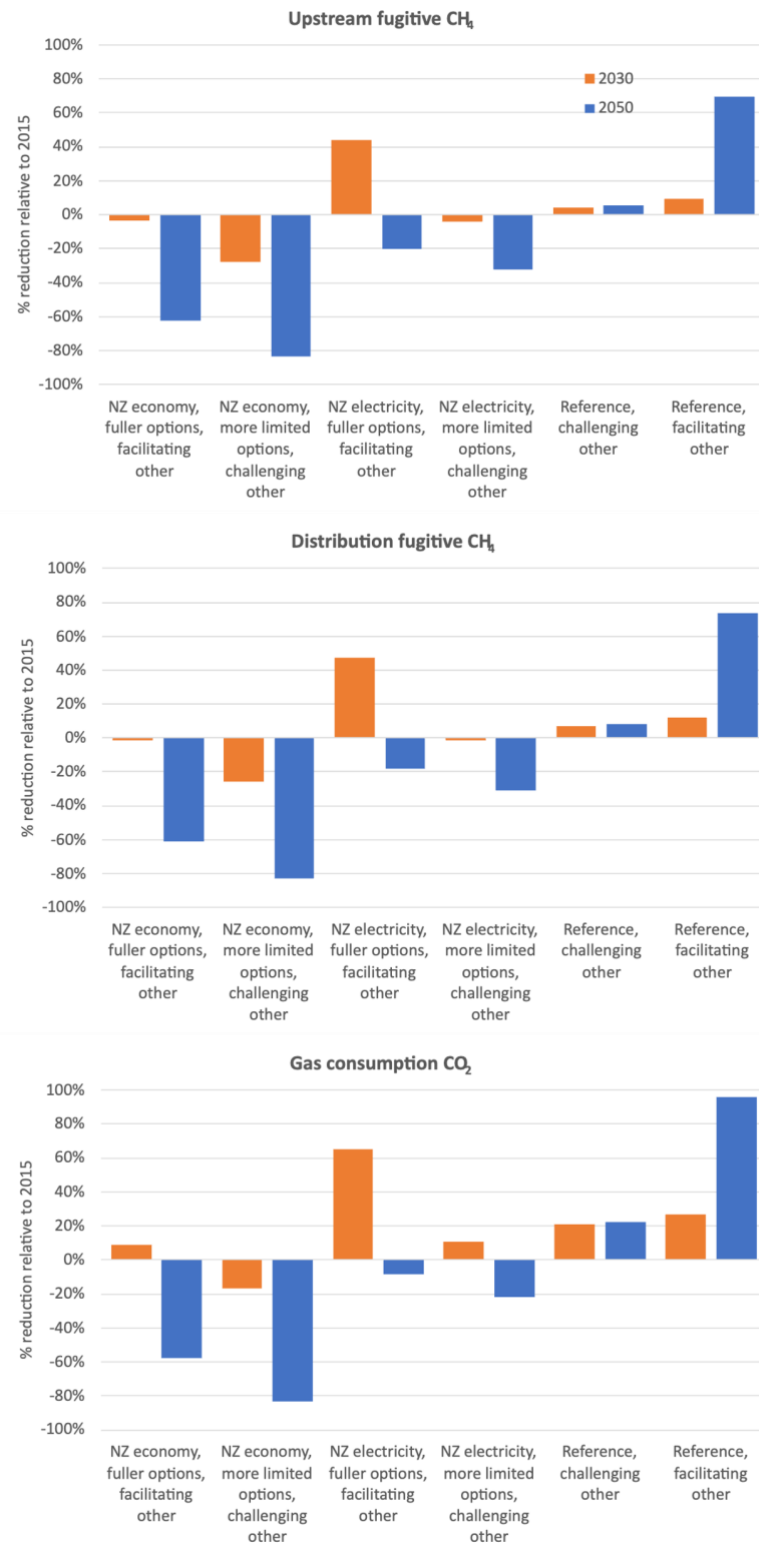


Figure BG2. Total regional gas consumption transitions for the required scenarios

Source: EPRI analysis

Figure note: Illustrative results for a Midwest region of the U.S. and for the illustrative scenario design and specification. Results will vary by region of the world and scenario design and specification.

Figure BG3 presents the 2030 and 2050 CH₄ and CO₂ emissions implications of the gas transitions in percentage change terms (relative to 2015). The figure illustrates that the gas market transitions could result in a fugitive CH₄ emissions decrease of 80% or increase of 70%. Gas consumption CO₂, on the other hand, could decrease by as much as 80% or increase by as much as 95%. The gas consumption CO₂ reduction percentage range differs from the CH₄ ranges because the CH₄ emissions are primarily a function of gas volumes, while the CO₂ emissions are a function of gas volumes and shifts in energy technologies and the overall make-up of the energy system. In Figure BG3, we also observe that the 2050 47% methane reduction AT is met in the two economy-wide decarbonization scenarios. Therefore, additional mitigation effort is not required in 2050 in these futures, but additional abatement effort is required in the other futures, as well as in 2030 since none of the scenarios reach the 37% reduction AT. The gas market transition to 2050 is not linear in any of the futures (Figure BG2). The CH₄ transitions follow these profiles and, therefore, additional abatement is required along the economy-wide transitions, as well as the other transitions. For CO₂, additional abatement is required under all the future conditions to meet the 2030, 2040, and 2050 AT targets.



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Figure BG3. 2030 and 2050 percent reductions in regional upstream fugitive CH₄, distribution fugitive CH₄, and gas consumption CO₂ for each required scenario

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Source: EPRI analysis

There are a variety of abatement measures that can be applied for fugitive CH₄ from gas production, processing, transmission, and distribution (EPRI, 2013; Table BG8). All seventeen measures shown in Table BG8 can be applied to upstream fugitive CH₄, and eleven can be applied to distribution fugitive CH₄. Furthermore, estimates of abatement costs for the set of measures can be used to evaluate the emissions reduction opportunities. Figure BG4 is an example of a marginal abatement cost curve for reducing gas distribution fugitive CH₄ emissions in our example region. The curve has been adjusted for negative cost options, which as noted in EPRI (2013) should be treated as omitted costs.

Table BG8. Natural gas fugitive CH₄ emissions abatement measures

Source: EPRI (2013)

1	Installing Catalytic Converters on Gas Engines and Turbines - Vented and Combusted Exhaust.
2	Reducing Methane Emissions from Compressor Rod Packing Systems
3	Directed Inspection and Maintenance
4	Replacing Wet Seals with Dry Seals in Centrifugal Compressors
5	Enhanced Inspection and Maintenance
6	Electronic monitoring at Large Surface Facilities
7	Installing Electronic Starters on Production Field Compressors
8	Fuel Gas Retrofit for BD valve - Take Recip. Compressors Offline
9	Installing Flash Tank Separators on Dehydrators (at production, transmission, and storage sites without flash tanks)
10	Convert Gas Pneumatic Controls to Instrument Air
11	Inspection and Maintenance at Transmission and Storage Facilities
12	Using a Portable Evacuation Compressor for Pipeline Blowdowns
13	Installing Plunger Lift Systems in Gas Wells
14	Reduced Emission Completions from Hydraulically Fractured Oil and Natural Gas Wells
15	Optimize Glycol Circulation Rates in Dehydrators (at production sites with/without flash tasks and gas assisted pumps)
16	Replacing High-bleed Pneumatic Devices in the Natural Gas Industry
17	Installing Surge Vessels for Capturing Blowdown Vents

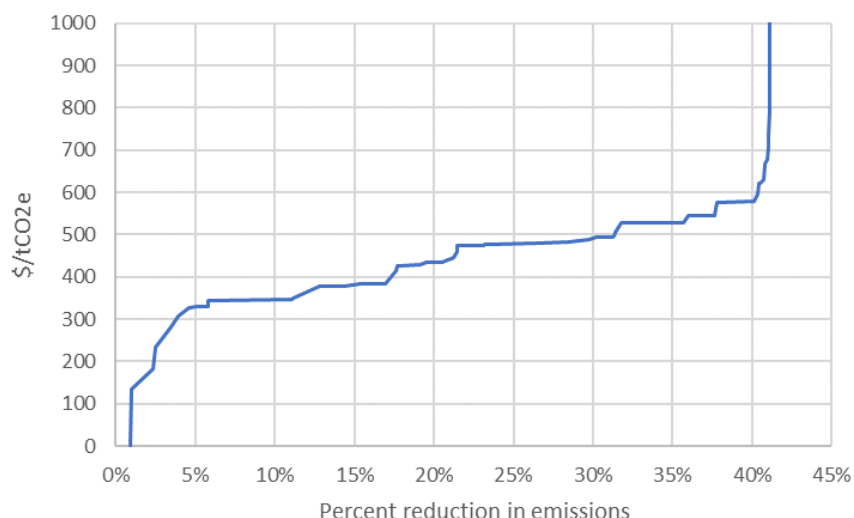


Figure BG4. Marginal abatement cost curve in 2030 for regional gas distribution fugitive CH₄ emissions

Source: Developed from EPRI (2013)

1 The marginal abatement cost estimates are then applied to the alternative CH₄ transition results (Figure
2 BG3) to evaluate the additional abatement costs for achieving the AT levels, as well as to evaluate the
3 costs of different reduction levels. Figure BG5 presents net present value cost results for achieving the
4 CH₄ ATs of 37%, 41%, and 47% reductions by 2030, 2040, and 2050 respectively under each of the
5 scenarios. The costs are for the additional abatement required in each scenario, where, as shown, some
6 scenarios produce declining emissions simply due to the decline in total gas consumption (Figures BG2
7 and BG3). CO₂ abatement costs are derived using the additional CO₂ abatement required in each scenario
8 for achieving the net CO₂ ATs of 56%, 88%, and 100% reductions by 2030, 2040, and 2050 respectively and
9 the implied CO₂ prices associated with achieving the decarbonization policies under the varying conditions
10 modeled.¹²

11
12 The uncertainty in the gas market (Figure BG2) is resulting in significant uncertainty in the cost of achieving
13 the targets. The net present value cost of achieving 47% reductions in upstream fugitive CH₄ by 2050
14 ranges from \$2.3 billion to \$868.1 billion. The cost of achieving 47% reductions in distribution fugitive CH₄
15 by 2050 ranges from \$19 million to \$95.8 billion; and, the net present value cost of achieving 100%
16 reductions in gas consumption CO₂ by 2050 ranges from \$7.3 billion to \$46.5 billion. The lowest cost
17 outcomes are associated with the transitions with the smallest gas market, which occur in the economy-
18 wide decarbonization transitions, with More Limited CO₂ decarbonization options, and with higher gas
19 prices (Challenging). The costs are highest when the gas market is largest, which is without a
20 decarbonization policy and when gas prices are lower (Facilitating). The extremely costly upstream fugitive
21 CH₄ outcomes of \$636 and \$868 billion are due to the early bump up in the size of the gas market in the
22 power sector decarbonization transition with Fuller decarbonization options and low gas prices in Figure
23 BG2 or the growing gas market in the no policy future with low gas prices. In both cases, the limits of the
24 fugitive CH₄ abatement measures are being reached, which is forcing use of the most expensive options.
25 When gas consumption is increasing, as is the case in these futures, the company is less likely to be able
26 to meet the 47% CH₄ reduction 2050 target due to the high costs. Even \$10-20 billion in abatement costs
27 might be a challenge, especially when we consider the total abatement costs across the three emissions
28 categories. This threshold is exceeded in other future conditions as well, such as in the power sector only
29 decarbonization transitions. Since the results in Figure BG5 are for the region, the company would scale
30 them for their system, utilizing the implied growth rates and/or their market share, to help them consider
31 their company-specific cost thresholds.

32
33 The results thus far highlight that the enabling conditions for the CH₄ targets are those conditions that
34 reduce the size of the gas market (economy-wide policy, higher gas prices, and more limited
35 decarbonization options), as well as cost improvements or additional options for fugitive CH₄ abatement
36 that help reduce the risk of high-cost outcomes. A smaller gas market, of course, has broader business
37 implications that the utility would want to consider. Note that Facilitating conditions can result in higher
38 costs for fugitive CH₄ abatement, but lower costs for gas consumption CO₂ abatement (not shown). This
39 is because the low gas prices result in a larger gas market, but they also make gas a more cost-effective
40 decarbonization strategy, while the other Facilitating conditions, such as slower load growth, lower
41 technology costs, and reduced additions barriers, also facilitate a less expensive transition to net-zero for
42 CO₂.

¹² In 2050, the implied CO₂ prices range from \$130 to \$1,330/tCO₂. The lower price is associated with Fuller-Facilitating conditions, while the higher price is associated with More Limited-Challenging conditions.

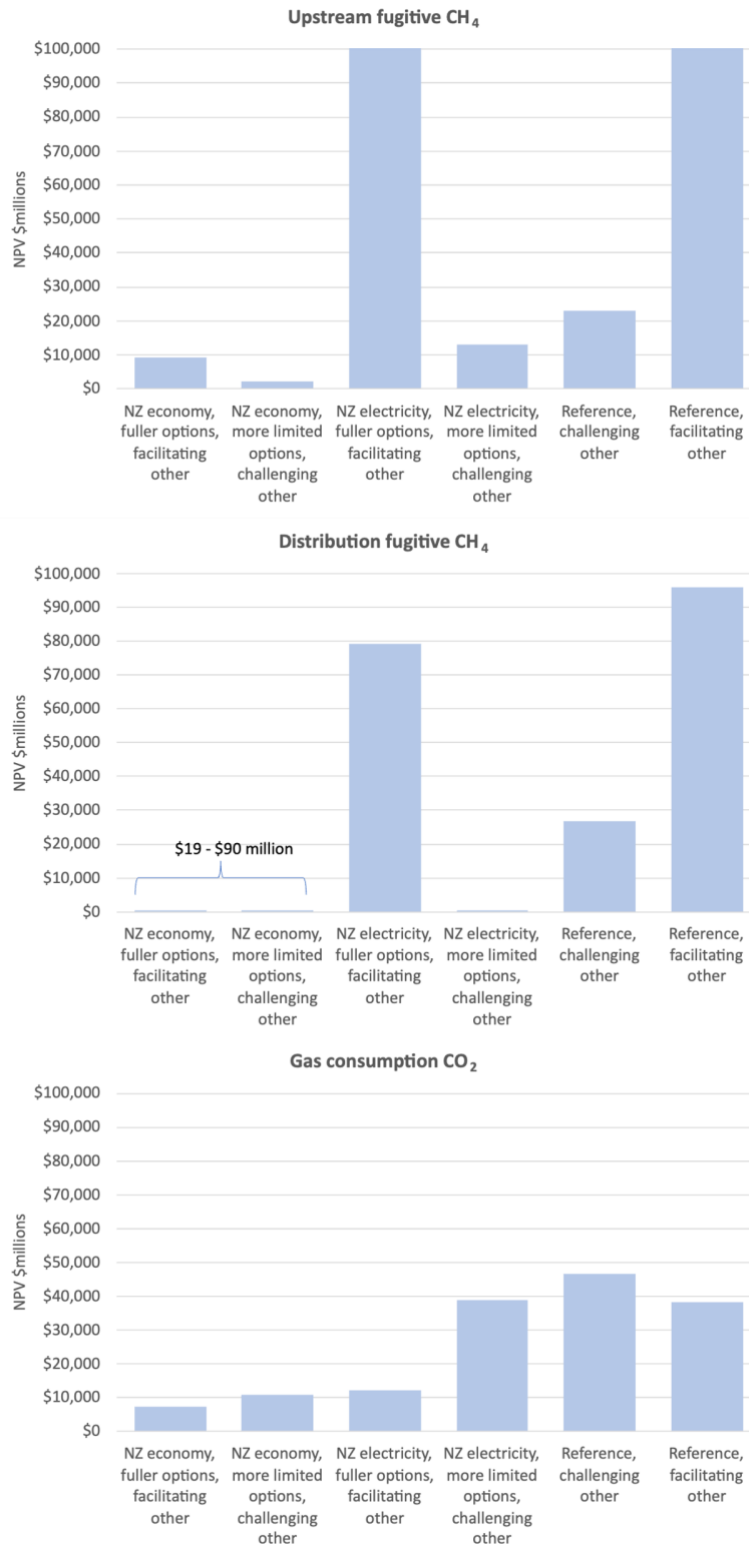


Figure BG5. Net present value additional abatement costs for reaching each of the fugitive CH₄ and gas combustion CO₂ ATs for each required scenario

Source: EPRI analysis

1 The company will also need to evaluate the level of abatement possible if future conditions are less
2 conducive to CH₄ and CO₂ abatement. Figure BG6 presents incremental net present value abatement cost
3 results for each of the fugitive CH₄ emissions categories for reducing emissions by 20%, 30%, 40%, or 47%
4 by 2050 and reducing gas consumption CO₂ emissions by 30%, 50%, 80%, or 100% by 2050. Note that, the
5 upstream fugitive CH₄ abatement cost curves for power sector decarbonization with Fuller options and
6 Facilitating conditions, as well as for Reference-Facilitating conditions are separated. This is because the
7 costs under these conditions are an order of magnitude higher, and therefore they are presented on a
8 different y-axis scale.

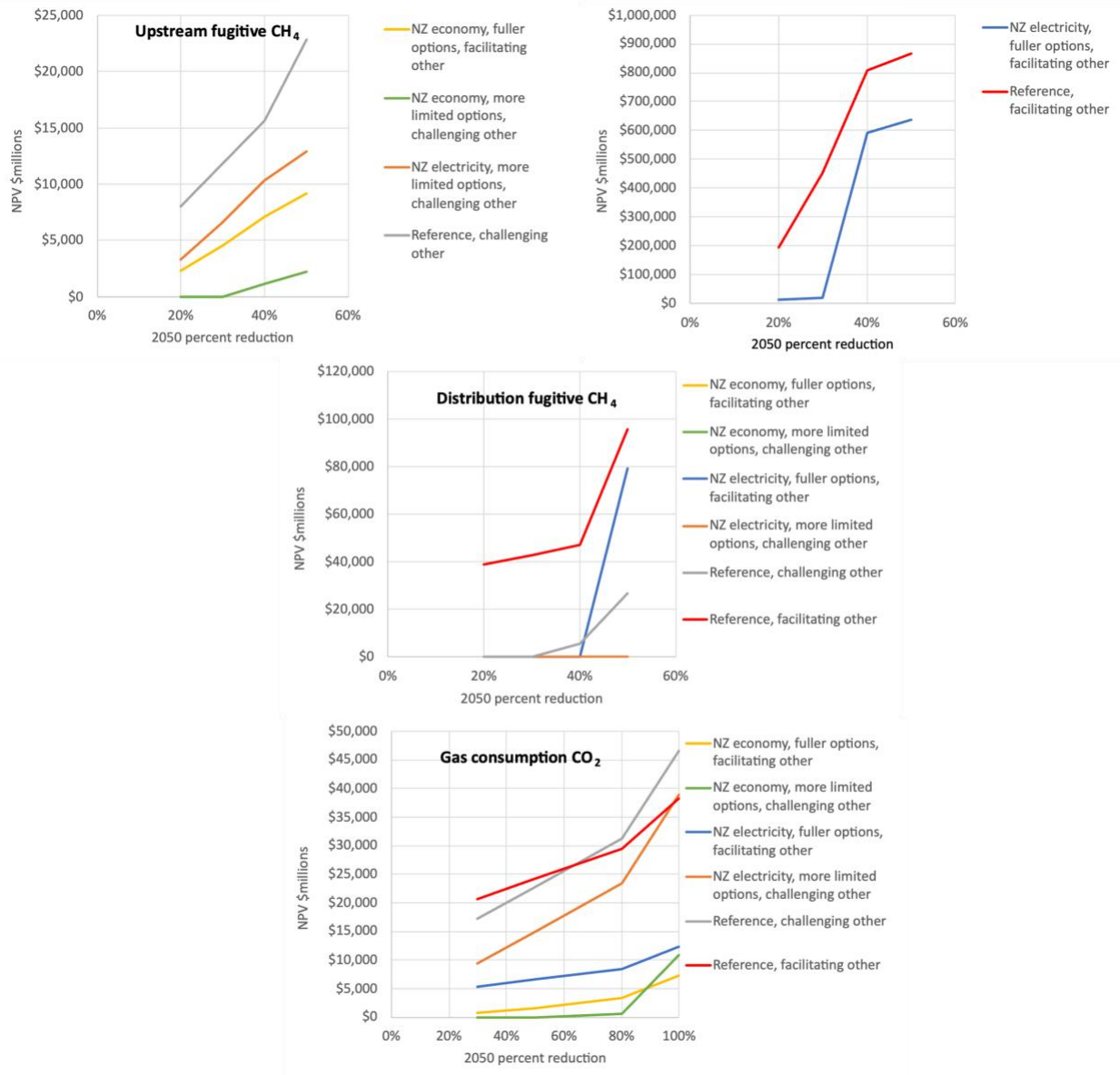
10 For abating the emissions from all three categories, we find that costs increase with the reduction level;
11 however, the levels and rates of increase depend on the emissions category and the conditions. We also
12 see notable cost uncertainty for all three categories and at every abatement level, with the variation in
13 costs across conditions varying by category. The different future conditions clearly affect the abatement
14 implications. For example, for the same cost of 20% reductions in upstream fugitive CH₄ with reference
15 conditions and high gas prices, 35% reductions could be achieved under power sector decarbonization
16 conditions, and 47% reductions could be achieved with economy-wide decarbonization conditions with
17 Fuller options and Facilitating conditions. Furthermore, for a quarter of the cost, 47% reductions could be
18 achieved with economy-wide decarbonization but More Limited and Challenging conditions where CDR is
19 unavailable and gas prices are higher.

21 Futures without a decarbonization transition and low gas prices (Reference-Facilitating) or with power
22 sector decarbonization and CDR and low gas prices (NZ Power-Fuller-Facilitating) are particular
23 challenging conditions for upstream fugitive CH₄ abatement, with the costs of 47% reductions high, and
24 even 20% reductions expensive. They are also the most challenging futures for distribution fugitive CH₄
25 abatement. These results illustrate that reducing gas fugitive CH₄ emissions depends heavily on conditions
26 that are not fully in the gas utility's control, such as economy-wide or electric sector decarbonization
27 transitions. Also, as noted earlier, factors favorable to cost-effective CO₂ reductions, such as CDR
28 availability and low gas prices, can increase the gas market size and make CH₄ reductions more
29 challenging.

31 For gas consumption CO₂, we clearly see the cost uncertainty of 100% reductions by 2050 under the
32 different conditions, with a net present value regional cost range of \$7.3 billion to \$46.5 billion. The upper
33 end represents the possibility of over six times the costs. If the more expensive conditions emerge, such
34 as reference and high gas price conditions, the company may have to reduce their emissions reduction
35 objective. For example, if \$10 billion is viewed as a threshold, abatement of 30%, 90%, or 100% reductions
36 could be supported if there is respectively electric sector decarbonization with More Limited options and
37 high gas prices, electric sector decarbonization with Fuller decarbonization options and low gas prices, or
38 economy-wide decarbonization with More Limited decarbonization options and high gas prices. The
39 company can estimate their costs from the regional results by considering their emissions share. With this
40 information, they can consider their company-specific cost thresholds and the corresponding emissions
41 reduction rates from the regional results.

43 Overall, the results from this step provide broad and transparent transition perspectives that are a useful
44 complement to company system planning. The results provide insights regarding potential transitions in
45 the gas market, as well as other aspects of the energy system that are relevant to the company's system
46 and service territory transition opportunities and CH₄ and CO₂ emissions reduction strategies.

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4 Figure BG6. Incremental net present value costs through 2050 for increasing 2050 emissions reduction targets
5 under the different future conditions for upstream gas production fugitive CH₄ (top), gas distribution fugitive CH₄
6 (middle), and gas consumption CO₂ (bottom)

7 Source: EPRI analysis

8 Figure notes: Abatement cost results for two of the upstream fugitive CH₄ abatement conditions are separate due to their
9 significantly higher costs and the need for an alternative y-axis range.

The set of results also provide milestone and contingency insights. For instance, the results suggest the need to evaluate in a few years which future is emerging to determine if the strategy needs to be adjusted. If, for example, no decarbonization policy is emerging for the regional power sector or economy, and gas prices are low, the company might have to reduce their emissions reduction plans or seek reasonably priced offsets for emissions too costly to directly abate. Similarly, if net-zero transitions are underway in the power sector or economy, the availability of CDR and low-carbon fuels options will matter. Both technology options will impact the fugitive CH₄ and gas consumption CO₂ emissions levels and abatement effort required. Other milestones might include end-use technology adoption, fugitive CH₄ abatement technology costs, low carbon fuel costs, and energy demand trends. The milestones related to the conditions that influence the gas market size and composition will be priorities.

It is important to keep in mind that transition opportunities and risks can vary dramatically between regions, with different possibilities, sensitivity to future conditions, and risks. See EPRI (2023) for examples of differences in regional gas markets, decarbonization opportunities, and risks within the U.S.

Outside of noting that they completed this phase, there is no other documentation requirement since it is an intermediate phase. SMARTargets requires documenting the final modeling results and insights in Phase 7 once iterations are complete. The company will, of course, be generating draft results and insights from this phase. However, those results are deliberative and documenting them can be confusing and misleading to audiences that are non-technical and that have not been intimately engaged in the development process.

Phase 5: Review potential transitions and target implications – based on decision-making needs

- *Phase inputs: Phase 4 preliminary transition analysis pathways and insights.*
- *Phase outputs:*
 1. *Preliminary insights regarding potential transitions, targets, and risks,*
 2. *Revisions to core scenario design, model implementation, and output reporting, and*
 3. *Additional recommended and sensitivity scenarios and specifications the company would like to evaluate.*
- *Who should be involved: Company decision-makers (e.g., directors, executives), staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.*
- *Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.*

For this phase, the company's planning, policy, sustainability, risk management, strategy, and outreach, staff, as well as external experts, will want to engage the company's decision-makers—directors and executives. The main objective here is to critically evaluate and discuss the preliminary results and insights and identify those they find reliable and meaningful. The additional objectives here are to identify any revisions to core scenario design, model implementation, and output reporting they might want to make, and to identify additional scenarios and specifications that the company would like to evaluate. The last two items emerge from the company's critique and discussion of the draft results and insights.

Given the need to identify enabling conditions, this is the time for the company to think concretely about trade-offs, risks, and risk management from their perspective. The Phase 4 discussion above highlighted related insights from the perspective of our example company and analysis, noting specific risks and

enabling conditions that identify and justify the company's QTs. Using the results from Phase 4, the company identifies trade-offs, risks, and risk management strategies. For instance:

- *Risks identified:* The primary risk is the size of the gas market, which is not only a risk in terms of the emissions abatement challenge, but also an overall revenue and operations risk for a gas utility. Related to gas market risk, there is also abatement cost and target attainability risk, where we find that there is the possibility of significantly higher costs associated with achieving the ATs in some plausible future conditions, especially for 47% reductions in fugitive CH₄ emissions by 2050.
- *Risk sources:* The gas market size risk is due to decarbonization transition, decarbonization option, and other uncertainties, with the size of the gas market responsive to whether there is a decarbonization transition and if it is in the power sector or economy-wide, whether the decarbonization options are fuller, and include carbon dioxide removal in particular, or more constrained, and whether gas prices are low or high and other conditions are facilitating or challenging the decarbonization transitions. Emissions abatement cost risk is a function of the gas market size uncertainty, as well as the cost and availability of fugitive CH₄ abatement options, and the cost-effectiveness of low carbon gas fuel options. The riskiest fugitive CH₄ abatement cost conditions are when the gas market is growing, which is projected to occur when there is no decarbonization transition, gas prices are low, CDR is available, and fugitive CH₄ abatement options are limited. The riskiest gas consumption CO₂ abatement cost conditions are when the gas market is flat or growing, which is projected to occur when there is no decarbonization transition, gas prices are high or low, and low-carbon technologies are more costly with slower cost improvement and barriers delaying new builds.
- *Risk management strategies:* Looking across the scenarios, we can identify enabling conditions and contingencies. The former are conditions that allow for a low-emissions transition with more manageable trade-offs. In this case, for fugitive CH₄ emissions, the conditions that result in a smaller gas market help reduce the level of CH₄ emissions and the challenge of abating CH₄. These include economy-wide decarbonization, higher gas prices, and more limited decarbonization options. In addition, research and development that lowers the cost and increases the availability of gas system fugitive CH₄ abatement technologies would help manage the abatement cost risk.

For gas combustion CO₂ abatement, economy-wide decarbonization, lower gas prices, and more decarbonization options help manage the cost risk. Note that, some of the conditions conducive to gas consumption CO₂ abatement are at odds with those conducive to gas system fugitive CH₄ abatement. Research and development is also a risk management strategy for gas consumption CO₂ abatement, where improving the cost-effectiveness and availability of low-carbon gas could help manage the abatement cost risk.

As for contingency strategies, if the company finds itself in a growing gas market future, CH₄ abatement costs may become prohibitive, and they may need to lower their emissions reduction target. For CO₂ abatement, the company would want to adjust the portfolio of CO₂ reduction strategies depending on the conditions. This would imply shifting the mix of strategies between

sourcing low-carbon gas, energy efficiency improvements, electrification, offsets, and emissions allowances (if available).

Given the set of results and insights, this company might specify QTs for 2050 of 20% for both fugitive CH₄ categories and 30% for gas combustion CO₂. The former being defined by what the company could support under Reference and low gas price conditions, where additional reductions could be pursued if any of the other conditions emerge where the gas market is not growing. Even 20% reductions would be difficult without offsets in futures resulting in a growing gas market (Reference-Facilitating and power sector net-zero with Fuller-Facilitating conditions). The CO₂ QT is defined by what the company could support under Reference conditions, where additional ambition could be pursued under all other conditions.

This phase is also the time when the company would want to consider the likelihoods of the different futures and potential hedging strategies they might pursue. For example, if the company believes that the likelihood of an economy-wide policy is low and Challenging conditions are more likely than Facilitating, they might want to invest more in R&D for gas system CH₄ abatement options, as well as explore and communicate what emissions reductions are possible if they cannot bring the abatement costs down.

After developing preliminary results and insights, the company would want to identify whether revisions to the scenario design, model implementation, and/or output reporting. In terms of identifying potential revisions to the scenario design and implementation in particular, the group discussion should consider whether they want to tweak anything. This could include revising what is included in each of the Fuller and More Limited decarbonization options sets, expanding Facilitating/Challenging to include additional uncertainties (e.g., CH₄ marginal abatement cost uncertainty), making the specifications more extreme to further differentiate them, or simply adjusting a specification such as the annual additions constraints for new electricity generating capacity or transmission. An additional option would be to add low-carbon gas cost uncertainty.

The company's discussion on potential sensitivity scenarios should look for meaningful adjustments to one or two assumptions. For example, based on the results above, this company might want to consider running More Limited with CDR scenarios (power sector and economy-wide net-zero) that add CDR to the More Limited decarbonization options set. They might also want to consider running an alternative power sector emissions target (e.g., 50% by 2050) to reflect the power sector's potential reductions without power sector decarbonization enabling conditions (see the potential QTs in the electricity generation supply emissions target setting example in this appendix).

Like Phase 4, outside of noting that they completed this step, there is no documentation requirement for the company since it is an intermediate phase. SMARTargets requires documenting the final modeling results and insights in Phase 7 once iterations are complete.

Phase 6: Revise and iterate as needed – revising scenario design, implementation, and model results

- *Phase inputs:*

1. *Phase 5 revisions to core scenario design, model implementation, and output reporting, and*
2. *Phase 5 sensitivity scenarios and specifications the company would like to evaluate.*

- *Phase outputs:*

1. *Revised insights regarding potential transitions, targets, and risks, and*
2. *As needed, additional revisions to scenario design, model implementation, and transition pathways.*

- *Who should be involved: Staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.*

- *Stakeholder engagement: This is a good time to seek external stakeholder feedback.*

- *Documentation: None. This is an intermediate phase. Phase 7 documents the final modeling results and insights once iterations are complete.*

For this phase, the company's planning, policy, sustainability, risk management, strategy, and outreach, staff, as well as external experts, will work together to revise the insights regarding potential transitions, targets, and risks, and, as needed, implement any needed revisions to the scenario design (core and sensitivity scenarios), model implementation, and transition pathways.

Phase 6 is also a good time for external stakeholder feedback. After internal iterations are complete, the company will have final drafts of their scenario design, results, insights, and strategies to share and discuss. This gives the company an opportunity for education and dialogue, as well as an opportunity to solicit feedback on their potential transitions, challenges, uncertainties, risks, enabling conditions, and collaboration opportunities.

For this phase, the company continues to iterate on the scenario design, specification, results, and insights until they have agreement with their decision-makers. Like Phase 5, outside of noting that they completed this phase, there is no documentation requirement for the company since it is an intermediate phase. SMARTargets requires documenting the final modeling results and insights in Phase 7 once iterations are complete.

Phase 7: Communicate results – targets, transitions, risks, enabling conditions, risk management

- *Phase inputs:*

1. *Phase 6 final scenario design (core and additional scenarios), model implementation, and transition pathways, and*
2. *Phase 6 final insights regarding potential transitions, targets, risks, enabling conditions, and risk management.*

- *Phase outputs:*

1. *Documented scenario analysis, outputs, and insights,*
2. *Aspirational Targets (ATs), strategies, and risk management, and*
3. *Qualified Targets and their qualifying conditions (QTs) and strategies.*

- *Who should be involved: The company’s decision-makers (e.g., directors, executives), staff related to planning, policy, sustainability, risk management, strategy, and outreach, as well as any external experts on scenario analysis and modeling with which you are collaborating.*
- *Documentation: SMARTargets Reporting Template summarizing the following:*
 1. *The company’s ATs and QTs with corresponding conditions,*
 2. *The company’s enabling conditions, strategy, risks, and risk management,*
 3. *The company’s transition risk analysis (modeling, scenario design and specification, potential transitions, insights), and*
 4. *The implementation process.*

This phase is the critical communications of all the company has done for the Step 4 analysis. For this phase, the company will want to work with their decision-makers and company planning, policy, sustainability, risk management, strategy, and outreach teams. They will also want to engage their external experts to help with documenting the methodology and effectively, rigorously, and defensibly communicating the results. The experts can also help the company communicate the relevant science to educate readers and ground the methods.

At the end of Phase 7, the company will use the SMARTargets Reporting Template to finalize the documentation for their Step 4 transition risk analysis (Phases 1 through 7). This includes the summary tables of key output indicators, as well as graphics to help communicate the company’s modeling results and insights. Additionally, the company will report the identified enabling conditions for ATs, QTs and corresponding conditions, and the risks and opportunities identified. Finally, the company will indicate their risk management strategies along with their milestones and contingency plans.

The company’s strategy will consist of more than targets. It will also include transition plans as well as strategies for pursuing enabling conditions and managing risks, where the latter might entail research and development plans, collaboration with customers or other sectors, and policy dialogue. Step 4 has a minimum set of required outputs (Table 20 in the methodology document). Additional variables may be added based on company need.

Step 5. Strategy and qualified target alignment with international goals

Step 5 Outputs: International goal alignment assessments of qualified targets and strategies.

In this step, the company will evaluate *qualitative* alignment of their transition strategy with the international goals, as well as *quantitative* alignment of their QTs.

Assessing qualitative alignment of the transition strategy

The company will assess two types of qualitative alignment of their strategy with international goals: (1) alignment with the types of transitions robustly observed in global emissions pathways consistent with the Paris Agreement temperature goals, and (2) alignment with the provisions in the Paris Agreement associated with achieving the temperature goals.

As discussed in the methodology document, the following are robust types of transitions found in all global 1.5°C and 2°C emissions pathways. The following are changes found consistently in well-below 2°C pathways regardless of the model and assumptions:

- Increasing low-carbon technology deployments,
- Increasing reliance on electricity,
- Transitions away from fossil fuels but continued use,
- Use of carbon dioxide removal,
- Improvements in energy conservation and efficiency,
- Differences in regional low-carbon transitions, and
- For any climate goal, substantial uncertainty in the levels, rates of change, and composition (e.g., technologies, energy, activity) of the transition of the global economy.

Methane reductions are also a robust characteristic of the global pathways, with reductions in CH₄ producing activity levels and the utilization of CH₄ abatement measures. The transition analysis results can be assessed for consistency with these robust Paris Agreement aligned transition characteristics. The assessment, however, is different from that for electricity generation emissions strategies since the utility is needing to consider alternative gas markets conditions that are primarily out of their control. The assessment here should therefore focus on the strategy elements the utility can control and influence. For example, in all cases the company strategy is reducing fugitive CH₄ and gas consumption CO₂ emissions by utilizing fugitive CH₄ and gas consumption CO₂ abatement technologies. The set of strategies also includes increasing deployment of low-carbon technologies and energy conservation and efficiency and the use of carbon dioxide removal. They also exhibit significant uncertainty in the transitions and of course, by design, recognize the unique regional transition opportunities.

Furthermore, the transitions and insights align with Paris Agreement's provisions recognizing differences in national decarbonization opportunities, multiple societal priorities, transparency, and the value of innovation and cooperation (in this case across sectors via the economy-wide scenarios).

Assessing alignment of the Qualified Targets

The company will also assess quantitative alignment of their QTs through comparison to the relevant global emissions pathway ranges consistent with the Paris Agreement objective of limiting global average temperature to "well-below" 2°C. Table BG8 shows this comparison. Based on the Step 4 transition risk analysis, we assume this utility identified the following fugitive CH₄ and gas consumption CO₂ sets of QTs:

1. Fugitive CH₄ QTs: 20% reductions by 2050 (with 16% and 17% reductions in 2030 and 2040), and
2. Gas consumption CO₂ QTs: 30% reductions by 2050 (with 10% and 20% reductions in 2030 and 2040).

The conditions associated with the fugitive CH₄ QTs include a growing regional gas market due to low gas prices, no decarbonization transition in the power sector or economy-wide or power sector only decarbonization with CDR available, and non-CDR offsets being unavailable. The conditions associated with the gas consumption CO₂ QTs include a flat or growing regional gas market due to no regional decarbonization transition in the power sector or economy-wide and non-CDR offsets being unavailable. The QTs were identified by primarily considering the transition implications for affordability and the companies threshold for manageable costs. Other factors could also be considered, such as new infrastructure requirements, operational reliability, and the likelihood of the future conditions.

Based on the Table BG8 comparison, this utility would conclude that their fugitive CH₄ QTs are quantitatively Paris Agreement aligned. However, the comparison for the gas consumption QTs is less

definitive. The 2030 QT falls within the well-below 2°C range, but the 2040 and 2050 QTs do not. As discussed in the methodology document, the QTs should not be judged negatively based on this comparison. This outcome is simply an indication of the company’s challenges. The QTs should be evaluated in terms of their challenges and the strategies for pursuing them and enabling conditions for additional ambition.

The high-level insight from the Table BG8 comparison is that QTs within the ranges are aligned with global futures consistent with limiting warming to well-below 2°C. Furthermore, if all companies have QTs within the range, the sum will also be aligned with well-below 2°C. However, it is important to keep in mind that this comparison is not conclusive because the global pathways do not capture the transition opportunities and challenges for individual companies, or differences across companies. In addition, the global pathway ranges do not reflect all the sub-global and local transitions found to be aligned with a global temperature. Thus, QTs for some companies are likely to fall outside the global pathway ranges due to their transition opportunities and challenges. The QTs represent the highest possible ambition for a company under different conditions while balancing trade-offs and risks that the company would be transparently identifying and communicating. In this example, the company would communicate what conditions are determining their QTs. The 30% by 2050 reduction in CO₂ was defined by a regional cost threshold of \$20 billion, which corresponds to a company-specific threshold of \$5 billion (25% of the cost based on the company’s market share). The QT is associated with Reference conditions without decarbonization transitions elsewhere in the regional economy. The company could also communicate how additional reductions would be possible under the other conditions.

Note that, this utility might also communicate fugitive CH₄ QTs greater than ATs. This occurs when there is a net-zero decarbonization transition economy-wide and the regional gas market shrinks.

Table BG9. Qualified Target Paris Agreement alignment assessment

Qualified Target set	Key qualifying conditions	GHG	Qualified Target 2050		Well-below 2°C ranges	Within range
Fugitive CH ₄	Growing regional gas market due to low gas prices, no decarbonization transition in power or economy-wide or power sector only decarbonization with CDR available, and non-CDR offsets unavailable	CH ₄	2030	-16%	13% to -60%	Yes
			2040	-17%	-5% to -65%	Yes
			2050	-20%	-4% to -78%	Yes
Gas consumption CO ₂	Flat or growing regional gas market due to no regional decarbonization transition in power sector or economy-wide and non-CDR offsets unavailable	Net CO ₂	2030	-10%	10% to -100%	Yes
			2040	-20%	-24% to -121%	No
			2050	-30%	-43% to -126%	No

The company can also visually communicate overall alignment with the Paris Agreement (PA). A graphic like Figure BG7 can be created and is an effective means to defensibly and quantitatively communicate ambition, as well as alignment of the company targets and transition risk analysis pathways with the Paris Agreement temperature goal. The company will want to include a narrative with Figure BG9 discussing the information shown and describing SMARTargets’ comprehensive Paris Agreement alignment—

quantitative, qualitative, and in the company-specific evaluation of two reduction types (ATs and QTs) that recognizes differences in transition opportunities, challenges, risks, and enabling conditions.

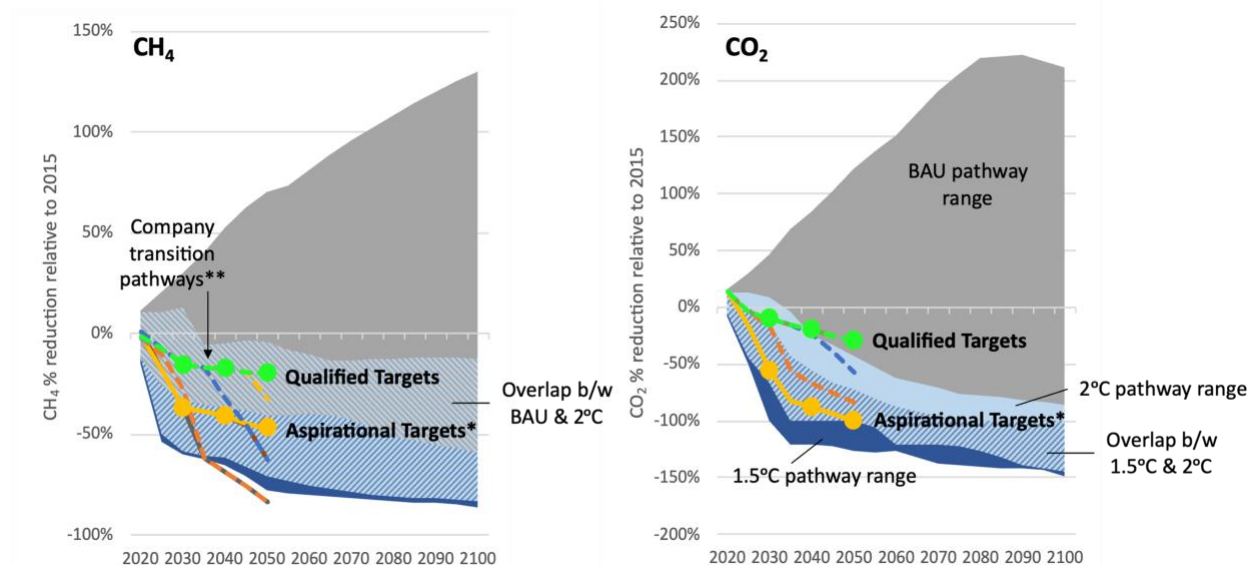


Figure BG7. Alignment of illustrative company fugitive gas CH₄ and gas consumption CO₂ Aspirational and Qualified Targets with the global emissions pathways consistent with the Paris Agreement temperature goals

Source: EPRI

Figure notes: Aspirational Targets denoted with yellow dots with solid line transition pathways. Qualified Targets denoted with green dots with dashed line transition pathways. Developed from EPRI (forthcoming) analysis of the IPCC's Sixth Assessment Report, IEA Net Zero by 2050, and other recent global emissions pathways, and the EPRI illustrative US-REGEN analysis completed for this example. See EPRI (forthcoming) and EPRI (2020 and 2018) for detailed assessments of recent and previous global emissions pathway modeling and results, including discussion of global pathway limitations and the importance of using full ranges due to the nature of the IPCC data. Solid and dotted lines indicate AT and QT transition pathways respectively.

* Enabling conditions may be needed to achieve the Aspirational Targets. See the company transition risk analysis and narrative that identifies the enabling conditions and Qualified Targets reductions and their qualifying conditions.

** Shown are the CH₄ and CO₂ transitions after the additional abatement required for achieving the Aspirational and Qualified Targets identified from the Step 4 transition risk analysis.

Step 6. Documentation and communication

Step 6 Output: SMARTargets documentation.

In this step, the utility will document and communicate their SMARTargets implementation using the SMARTargets Reporting Template. This includes documenting implementation choices with justification, transition analysis insights, targets, strategy, and milestones. Through the template, the following information will be assembled:

- General company information and stakeholder engagement,
- GHG Inventories and base year,
- Practical issues and climate target groupings,
- Company transition risk analysis of opportunities and risks,
- Alignment assessment,

- Documentation and communication of targets, strategies and indicators, and
- Implementation and monitoring.

The set of information represents a clear, comprehensive, and transparent package of information about the process and the outcomes. Overall, in applying the methodology, the utility will produce the following standardized and comparable results that reflect their implementation and climate strategy:

- i. Paris Agreement-aligned targets and enabling conditions, including Aspirational Targets (AT) and Qualified Targets (QT) and their associated conditions,
- j. Insights into potential low-carbon transitions,
- k. Assessment of risks, risk management strategies, and overall transition strategy, and
- l. Documentation of methodology implementation, including:
 - GHG inventory by required emissions category,
 - Responses to practical considerations and target-setting decisions for each category,
 - Transition risk analysis components:
 - Modeling approach
 - Reference conditions and key uncertainties
 - Core scenario definitions and specifications
 - Criteria for identifying risks and enabling conditions

In addition, the company is encouraged to holistically communicate their strategy. This goes beyond emissions targets and includes leadership strategies to help create the enabling conditions for achieving greater emissions reductions and economy-wide decarbonization, such as research and development (R&D), educational outreach (stakeholder and policy), and collaboration and coordination with customers and supply chain partners. For this illustrative utility, the analysis has identified that risk management is important given the significant uncertainty and lack of control over the size and composition of the gas market. Among other things, for fugitive CH₄, this could include research and development that lowers the cost and increases the availability of gas system fugitive CH₄ abatement technologies. For their largest source of emissions, gas combustion CO₂, abatement cost risk management might include encouraging the availability of additional decarbonization options and research and development that improves the cost-effectiveness and availability of low-carbon gas. Recall, some of the conditions conducive for gas consumption CO₂ abatement are at odds with those conducive for gas system fugitive CH₄ abatement. For all three categories of emissions, offsets (CDR and non-CDR) would help the utility achieve the targets, increase ambition, and manage trade-offs.

Finally, the company would also want to consider communicating on the SMARTargets Methodology itself, including its scientific foundations. This can involve referencing the publicly available methodology, the SMARTargets Scientific Foundations, and other materials and emphasizing how the approach is science-based and aligned with the Paris Agreement (see Justification for the Methodology section).

Step 7. Validation and Verification

Step 7 Outputs: Validated SMARTargets and verified progress.

In this step, the utility will validate their SMARTargets and verify progress. After completing the SMARTargets Reporting Template in Step 6, the utility will be able to initiate validation activities. Validation assesses whether the methodology has been properly implemented and whether the target

and strategy—by nature forward-looking statements—are supported by sound assumptions, data, and methods. The primary input for validation is the SMARTargets Reporting Template.

The utility will begin with internal validation, leveraging internal audit processes aligned with recognized standards. This step ensures the methodology has been correctly applied and that the resulting targets and strategies are scientifically grounded and aligned with the Paris Agreement. Internal validation also builds confidence by thoroughly documenting the rationale and process behind the targets—information that is essential for both third-party validation and external communications.

Internal validation is all that is possible in the near-term. Accredited, independent third-party validation services for corporate GHG targets do not currently exist. Third-party validation is recommended once it becomes available. It provides an independent, authoritative assessment of conformity with the SMARTargets Methodology and validation criteria.

Following validation, the utility will communicate the results to the public, including regulators, investors, and other interested stakeholders.

In addition to validating, the utility is required to verify progress periodically. The utility will evaluate actual emissions reductions against its targets using the most recent GHG emissions inventory. The same third-party provider that verifies the GHG inventory could also perform this progress verification, thereby ensuring consistency and credibility with reporting. This verification relies on GHG inventories, which are based on observable data and are therefore subject to assurance-level assessments.

Step 8. Monitoring and adjusting

Step 8 Outputs: Periodic milestone assessment and, as needed, strategy adjustment and/or SMARTargets refresh.

Under this step, the company will annually monitor their milestones and adjust their strategy as needed. The utility will need to monitor conditions with respect to their milestones to determine if strategy adjustments are needed and/or if updated SMARTargets analysis, targets, and strategies are needed.

The transition risk analysis (Step 4) provides milestone and contingency insights as well as insights regarding transition opportunities and risks. The company should articulate meaningful and observable milestones, and potential responses, based on their analysis, with the milestones clearly communicated in the Reporting Template. For instance, the Step 4 results above suggest the need to evaluate which future is emerging. If, for example, regional decarbonization transitions are emerging in the power sector or economy-wide, and/or offsets are available, the utility could pursue additional emissions reduction ambition beyond their QTs. Other key milestones identified include gas prices, the availability of CDR, electrification trends, and the costs and availability of fugitive CH₄ abatement technologies and low-carbon gas.

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