



Technical Appendices

Opportunities for Industrial Modernization in Washington: Technical Pathways, Investments, Policy, and Decarbonizing Options for Emission-Intensive, Trade-Exposed Industries

June 2025

Table of Contents

Appendix A: Stakeholder interviews.....	2
Appendix B: Value of EITE no-cost allowances, no linkage scenario	3
Appendix C: Modeled allowance prices under linkage scenario.....	5
Appendix D: Technical pathways methodology	6
Appendix E: Additional technical decarbonization pathway information.....	8
Appendix F: New electricity demand and pathway implementation costs from analysis	8
Appendix G: Permitting and siting.....	9

Appendix A: Stakeholder interviews

RMI spoke with stakeholders across more than two dozen different entities while developing this report. Through interviews, we spoke with a majority of the members of the Washington Department of Ecology Cap-and-Invest EITE Industries Advisory Group and the Cap-and-Invest EITE Policy Advisory Group, although some stakeholders we spoke to were not included in either of these groups. Organizational members of each group are listed in Exhibit A1.

Exhibit A1

Organizational Members of the EITE Industries Advisory Group	Organizational Members of the EITE Policy Advisory Group
Nutrien	Climate Solutions
Alliance of Western Energy Consumers	Washington Public Ports Association
Kaiser Aluminum	United Steelworkers Union - Local 338
Nippon Dynawave Packaging	The Nature Conservancy
Glass Packaging Institute	IAM 751
HF Sinclair	Clean and Prosperous
Collins Aerospace	Puget Sound Energy
Par Pacific and U.S. Oil and Refining	Washington Conservation Action
Cardinal FG Company	SEI Fuel Services (7-Eleven)
Northwest Pulp & Paper Association	Cowlitz Public Utility District No. 1
Lamb Weston	
Western States Petroleum Association	
bP America	
Association of Western Pulp and Paper Workers	
CRH Americas Materials/Ash Grove Cement	
Boeing	
Food Northwest	
Nucor Steel Seattle	
Packaging Corporation of America	
J.R Simplot Company	
TSMC Washington	
Phillips 66 Company	
Matheson Tri Gas	

Interviews — conducted between November 2024 and April 2025 — were oriented around topics including:

- Feedback on RMI’s proposed decarbonization pathways, including technology feasibility, costs, and implementation timelines
- Washington facilities’ priorities for industrial decarbonization
- Perspectives on the structure of the Cap-and-Invest program, uses of the revenue generated through the program, and the future of no-cost allowance allocations
- The largest barriers to and opportunities for industrial decarbonization, including issues like clean electricity availability and state permitting procedures.

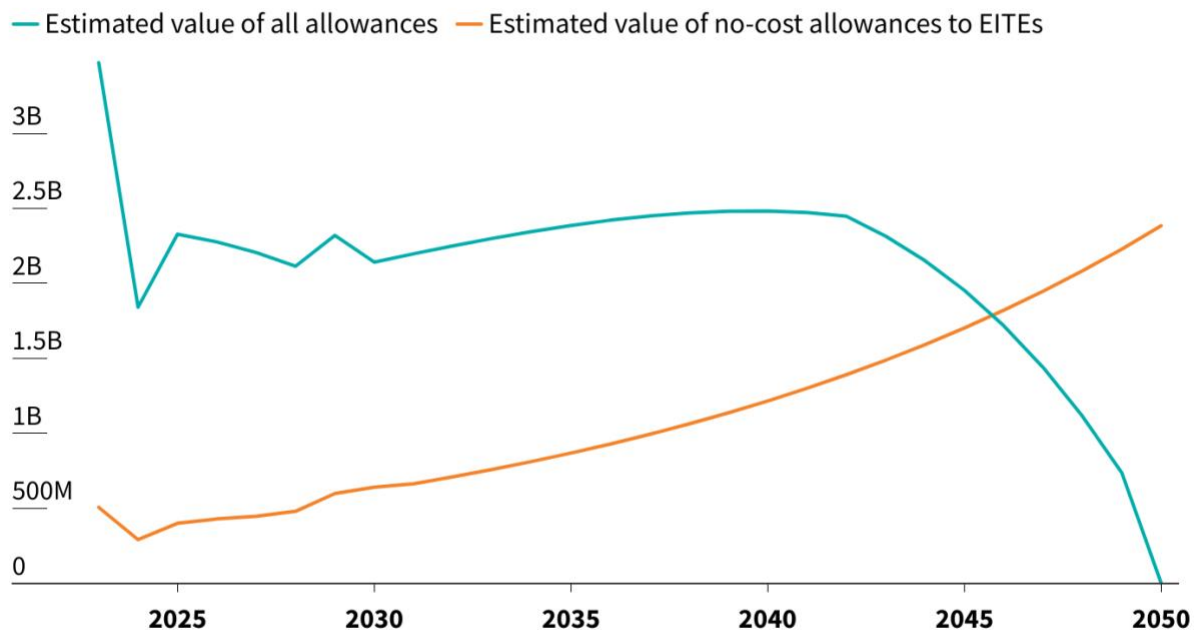
Where relevant, RMI has attempted to take interviewee feedback into account throughout the report.

Appendix B: Value of EITE no-cost allowances, no linkage scenario

Exhibit B1

Estimated value of Cap-and-Invest program allowances (\$)

The estimated value of no-cost allowances to EITEs without linkage begins to exceed the estimated value of all allowances beginning in 2046.



Allowance prices based on historical sale prices for 2023–24. Price estimates for 2025–29 based on average of Washington Department of Ecology baseline auction price forecasts (excluding APCR, ECR, & ceiling prices) for auctions held in a calendar year. Prices for 2030–50 based on historical and baseline price forecast average annual percent change. Overall level of allowances and allowances to EITEs based on RMI estimates from statutory annual cap levels and reductions relative to existing baseline, and excludes no-cost allowances to electric and natural gas utilities.

Chart: RMI • **Source:** Washington Department of Ecology.

To estimate the 2023-2025 values of EITE no-cost allowances, Exhibit 2 relies on an average of annual no-cost allowance allocations to EITEs as published by the Washington Department of Ecology to determine the volume of no-cost allowances allocated to EITEs over that period. Volumes of EITE no-cost allowance allocations between 2026 and 2050, assuming no linkage and with no change to no-cost allowances post-2034, were determined using the reduction schedule as outlined in the Washington Administrative Code.

To determine the volume of all allowances, which was then used to estimate the value of all allowances between 2023 and 2025, this analysis used total Cap-and-Invest program baseline and total Cap-and-Invest program information as published in Washington's Administrative Code.

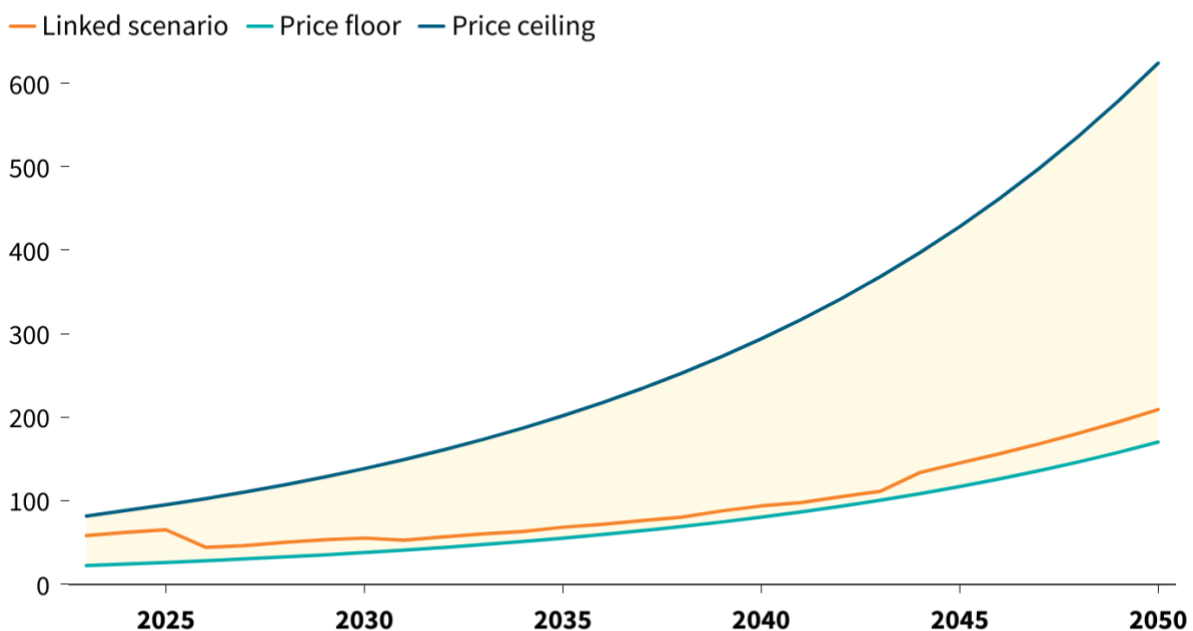
Average annual vintage auction prices as published by the Washington Department of Ecology were used for 2023 and 2024 prices and were multiplied by the volumes as determined above to derive allowance values for those years. Estimates derived from the Washington Department of Ecology's price forecasts were used to estimate annual prices between 2025 and -2029, and average rates of change were used to estimate prices thereafter, through 2050.

Appendix C: Modeled allowance prices under linkage scenario

Exhibit C1

Modeled Cap-and-Invest program allowance prices under linkage scenario beginning 2026 (\$)

If Washington links its Cap-and-Invest program to the California and Québec carbon markets ("linked scenario") beginning in 2026, forecast linked prices are between forecast price ceiling and price floor amounts through 2050.



Linked scenario values use modeled frontloaded allowance prices for 2023–25 and estimated modeled linked prices for 2026–30 from Vivid Economics. Estimated modeled linked prices for 2031–45 from Resources for the Future (RFF). Estimated modeled linked prices for 2046–50 calculated by RMI from RFF estimated changes. 2023–25 price floor and ceiling values from historical auction prices published by Washington Department of Ecology. Price ceiling and floor values for 2026–50 calculated by RMI from estimated adjustment factor based on state statute.

Chart: RMI • **Source:** Vivid Economics, Resources for the Future, Washington State Department of Ecology, and RMI.

The inputs used to produce the 2023-2045 “linked scenario” values in Exhibit C1 are derived from a study Vivid Economics conducted for the Washington Department of Ecology in 2022 and from a study Resources for the Future (RFF) published in 2025. Linked scenario values for 2045-2050 were estimated based on the average annual rate of change from RFF’s estimates.

The price floor and ceiling values for 2023-2025 were derived from historical auction prices published by the Washington Department of Ecology. For price ceiling and floor values between 2026 and 2050, RMI estimated those values based on the Washington Administrative Code’s language that ceiling and floor prices are the ceiling or floor price for the prior calendar year, increased annually by 5% plus the rate of inflation based on the most recently available 12 months

of the consumer price index for all urban consumers (CPI-U). RMI then determined the 10-year average annual CPI-U rate of change and applied it, in conjunction with the specified 5% annual increase, to the most recent historical price floor and ceiling values through 2050.

Appendix D: Technical pathways methodology

To estimate the decarbonization potential of Washington's EITE sectors, the analysis integrates facility-level emissions data with sector-wide applicable relative emissions reductions for each of the selected technologies modeling. The goal is to quantify realistic, cost-effective emissions reduction opportunities through 2050, using consistent baseline assumptions and technology performance parameters.

The evaluation draws on published academic literature, industry case studies, conducted interviews, and modeling reports to assess a range of decarbonization technologies. Each option was characterized by its expected relative GHG emissions savings per site, capital expenditure and marginal abatement cost, and estimated implementation timeframe. Relative reduction values were primarily sourced from peer-reviewed studies such as those from the Journal of Cleaner Production, as well as US DOE and EU industrial transition reports and RMI research and modeling. These percentages were applied to each facility's baseline emissions (average for 2015–2019 reported emissions) to estimate total achievable reductions in a comparable and consistent manner by 2035 and 2050 respectively.

Marginal abatement costs and gross Capex estimates were obtained from real-world project documentation, industry databases, and synthesis studies on industrial decarbonization economics including DOE reports. Sources included documented pilot projects (e.g., electrified boilers, CCUS retrofits) and aggregated reviews of capital and operating expenditures across industrial decarbonization pathways. Where ranges were given, midpoints or conservative values were used to derive cost-efficiency ratios (\$/ton CO₂e reduced annually). Additionally, following our stakeholder interviews, we adjusted both capital expenditure and marginal abatement cost estimates to reflect real-world constraints. For example, several food-sector operators confirmed that while full electrification remains a technically feasible long-term pathway, the steep up-front investment and integration challenges with existing steam systems made it impractical within our 2050 cost-optimization framework. Consequently, full-scale electrification was excluded from the final emissions reduction portfolio for this sector (while remaining possible given technological breakthroughs and significant cost reductions), and its potential was instead captured implicitly through partial electrification measures with lower capital expenditure and more favorable marginal costs.

Estimated implementation timelines were drawn from project development cycles observed in commercial deployments and construction benchmarks cited in existing literature and case studies. Technologies were grouped into near-term, medium-term and long-term categories based on technical readiness level, infrastructure requirements, permitting complexity, costs, and emission reductions potential. For example, measures like fugitive methane control and rate adjustments have shorter lead times, while large retrofits like green hydrogen integration and FCC gas carbon capture require multi-year planning and investment.

To translate facility-level decarbonization pathways into a sector-wide emissions reduction potential and to derive the sector's total abatement cost we follow a structured, transparent, and replicable procedure:

1. Compile baseline emissions by sector
 - Gather reported 2015–2019 CO₂e for each of the facilities reporting GHG emissions and calculate average emissions (E_i)
2. Select and characterize decarbonization technologies
 - For each facility, identify feasible options (e.g., electrification of boilers, FCC CCU, biorefinery retrofit, hydrogen fuel switching).
 - For each technology j at facility i , collect:
 - Relative reduction factor (r_{ij} , % of E_i)
 - Marginal abatement cost (MAC_{ij} , \$/tCO₂e) from case-study data and peer-reviewed literature and DOE reports
3. Compute technology-level absolute reductions

For each facility-technology pair:

$$\Delta E_{ij} = r_{ij} \times E_i$$

Example: A 20% reduction at a 1.0 MtCO₂e facility yields 0.2 MtCO₂e/y abatement.
4. Calculate total abatement cost per technology
 - Use literature and case study MAC values rather than deriving from capital costs due to limited data availability.
 - Compute $cost_{ij} = MAC_{ij} \times \Delta E_{ij}$
(e.g., \$50/t \times 0.2 Mt = \$10 M).
5. Sequence and adjust for overlap
 - Order technologies in operational sequence (e.g., efficiency \rightarrow electrification \rightarrow CCU).
6. Aggregate to facility and sector totals
 - Sum absolute abatements at each facility: $\Delta E_{i,total} = \sum_j \Delta E_{ij}$
 - Sum costs across all technologies and all facilities: $Cost_sector = \sum_{ij} cost_{ij}$
 - Sum total abatement: $\Delta E_sector = \sum_i \Delta E_{i,total}$
7. Calculate emissions reduction potential for 2035 and 2050
 - Projected business-as-usual emissions: Estimate total sector emissions for target years 2035 (E_{2035}) and 2050 (E_{2050}) using industry growth forecasts, policy scenarios, and assumed technology adoption rates.
 - Absolute Reduction Potential: Calculate the difference between the baseline sector emissions ($E_{baseline}$) and projected emissions:
 - $\Delta E_{2035} = E_{baseline} - E_{2035}$
 - $\Delta E_{2050} = E_{baseline} - E_{2050}$
 - Relative Reduction Potential: Express ΔE_{2035} and ΔE_{2050} as a percentage of the baseline emissions to facilitate cross-sector comparisons.

Appendix E: Additional technical decarbonization pathway information

Exhibit E1

WA State EITE 2022 emissions

■ Building Products, Electronics and Aerospace Manufacturing ■ Food Processing and Manufacturing ■ Petroleum Refining and Chemical Manufacturing ■ Pulp, Paper, and Cement Manufacturing ■ Steel, Aluminum, and Glass Manufacturing

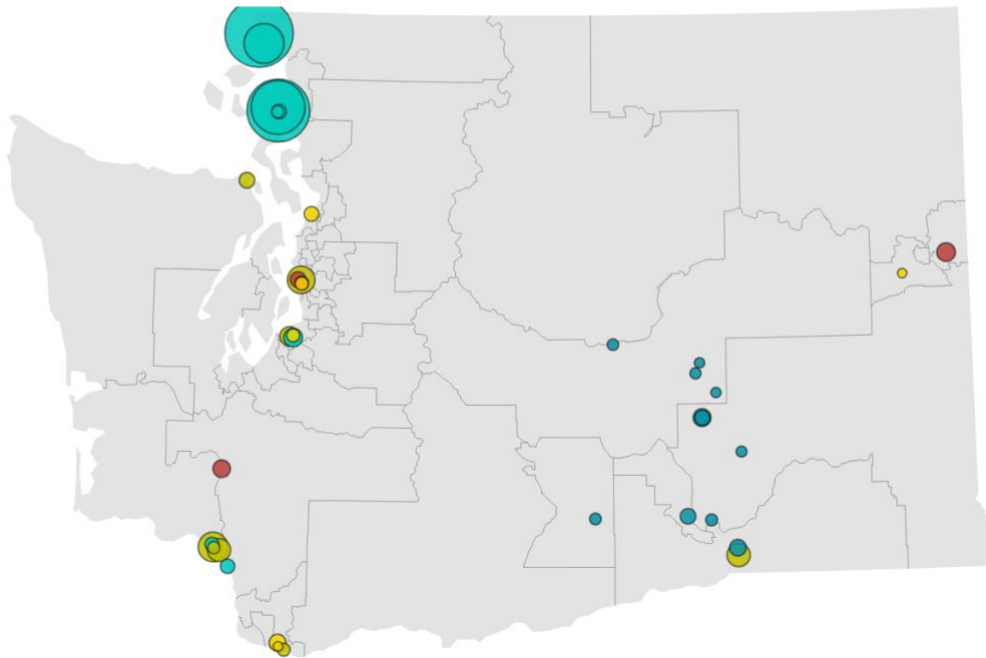
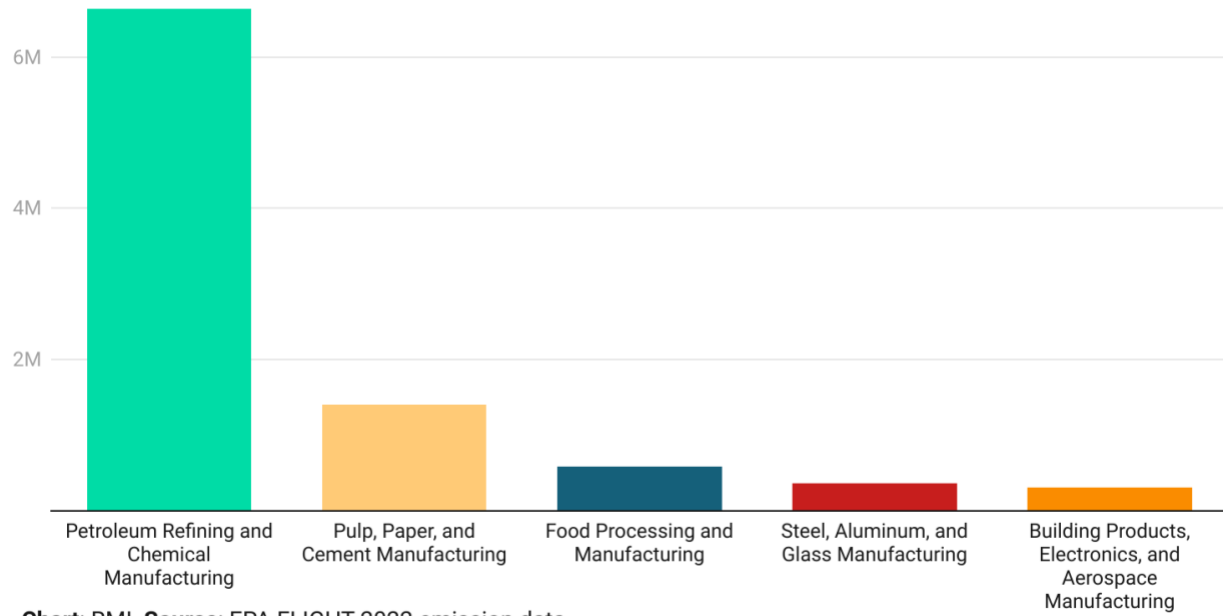


Exhibit E2

Annual emissions by EITE sector (tons CO₂e)



Created with Datawrapper

Exhibit E3

Refineries

Sector snapshot



Pulp and paper

Sector snapshot



Cement

Sector snapshot



Glass production

Sector snapshot



Food processing

Sector snapshot



Chemicals and hydrogen

Sector snapshot



Iron and steel

Sector snapshot



Electronics

Sector snapshot



Appendix F: New electricity demand and pathway implementation costs from analysis

Exhibit F1

	Annual additional electricity demand in 2030 (GWh)	Annual additional electricity demand in 2050 (GWh)	2035 Cost \$M	2050 Cost \$M
Refineries	4639.5	5522.6	\$1,61	\$10,284
Pulp and paper	1242.4	3574.1	\$978	\$5,010
Cement *	278.1	931.0	\$70	\$681
Glass *	163.9	526.2	\$51	\$414
Food processing	625.5	1704.4	\$58	\$260
Chemicals and hydrogen	232.1	686.8	\$69	\$344
Iron & steel	224.7	683.1	\$99	\$487
Electronics	161.6	347.0	\$4	\$20
Total additional electricity demand in 2030	7567.8			
Total additional electricity demand in 2050		13975.2		
Total cost by 2035			\$2.94B	
Total cost by 2050				\$17.5B

*Baseline loads for glass and cement sectors were estimated, while all other sectors are based on actual data.

Appendix G: Permitting and siting

The Washington State Departments of Ecology and Commerce produced the *Low-Carbon Energy Project Siting Improvement Report* which made 73 recommendations related to permitting and siting. Subsequently, the Washington legislature passed H.B. 1216 relating to permitting and siting. RMI evaluated H.B. 1216 against the recommendations from Ecology and Commerce. When evaluating H.B. 1216 against the recommendations in *Low-Carbon Energy Project Siting Improvement Report*, we found the following goals were fully addressed: EJ-4, EJ-6, Tribal-1, Tribal-2, Tribal-3, Tribal-4, Tribal 5, Tribal-10, Tribal-13, Tribal-17, Local-3, Local-7, Local-8, EE-1, EE-2, EE-7, Plan-2, Assist-10, Coord-2, State-1. Exhibit 15 below includes the recommendations we consider to be partially addressed or unaddressed by H.B. 1216.

Exhibit G1

Goal ID	Recommendation	How it is addressed
EJ-1	Develop detailed guidelines for agencies and local governments to engage overburdened communities as part of planning processes in equitable and accessible ways	Partially addressed — engagement encouraged, but detailed guidelines not mandated.
EJ-2	Consider how local government could coordinate with communities to develop guidelines on how best to engage with representative organizations.	Unaddressed — no requirement for local governments to develop engagement guidelines with communities.
EJ-3	Coordinate with communities on options to provide longer timelines for review and comment on permits.	Partially addressed in Section 303(2) — some flexibility implied, but extensions not mandated.
EJ-5	Consider providing funding for local governments, Tribes, and communities to provide information and training directly to developers on meaningful engagement.	Unaddressed — no funding provisions created.
EJ-7	Require environmental justice impact analysis be conducted as part of a state environmental review process or other related review process.	Partially addressed — nonproject reviews require EJ consideration, but no universal project-level EJ analysis.
EJ-8	Consider developing guidance and best practices for conducting impact analysis for overburdened communities.	Partially addressed — analysis in nonproject reviews, but no general guidance issued.
EJ-9	Incorporate equity consideration in requests for proposals for consumer-owned utility projects, similar to Washington Utilities and Transportation Commission requirements.	Unaddressed — utility RFP requirements not updated.
EJ-10	Agencies not covered by the HEAL Act should review the benefits of opting in.	Unaddressed — no directives to opt into HEAL Act participation.
EJ-11	Opt-in agencies with a nexus to clean energy siting or permitting should consider participating in the HEAL Interagency Work Group.	Unaddressed — no references to expanding HEAL Interagency Work Group participation.

TRIBAL-6	When assessing Tribal lands and interests that may be directly, indirectly, or cumulatively affected by a project, the evaluation should include Tribal treaty reserved rights, Tribal reservations, off-reservation rights, Trust lands, other Tribal-owned land and other areas of significance to Tribes.	Addressed in Sections 209(1) and 302(3)(a) — impacts considered, but cumulative effects not fully addressed and trust lands and other areas of significance not mentioned.
TRIBAL-7	Fund and request individual Tribes to self-identify their areas of interest.	Unaddressed — no funding mechanism provided.
TRIBAL-8	Develop map layers for routes of migratory species, vessel traffic routes or other information of interest to Tribes.	Partially addressed in Section 302(6) — Mapping mentioned, but as a final nonproject environmental review document, not a comprehensive mapping project, and species/vessel layers not explicitly required.
TRIBAL-9	Consider creating high-level map layers where a Tribe could self-identify areas of interest and provide contact information for early communication regarding potential projects.	Partially addressed — Mapping tools are required for projects but no self-identified tribal interest layer is mandated.
TRIBAL-11	Require ongoing monitoring of facilities for impacts to treaty resources.	Unaddressed — Monitoring encouraged but not required.
TRIBAL-12	Consider options to provide state funding for Tribal staff for clean energy planning and project reviews.	Unaddressed — No funding mechanism created.
TRIBAL-14	Support sufficient federal funding for Tribal staff to meet federal requirements for project reviews.	Unaddressed — Federal coordination not addressed in the law.
TRIBAL-15	Consider how the state could assist Tribes to develop clean energy projects.	Unaddressed — Focus is on project permitting, not Tribal project development.
TRIBAL-16	Consider how to provide additional funding and staffing to state agencies and Tribal Historic Preservation Officers to support Tribal consultation and engagement work related to clean energy projects.	Partially addressed — Coordination supported but no funding mechanism included.
LOCAL-1	Consider how to assist counties and cities in updating local codes for emerging clean energy technology by providing template language that could be modified locally.	Partially addressed — Coordinated permitting helps, but no code templates or planning guidance are provided.
LOCAL-2	Expand training opportunities for local governments on clean energy processes and regulations, emerging technologies and on Tribal affairs and relations.	Partially addressed in Section 102(1)(g) — Developer training is included, but local governments may not be included in developer trainings.
LOCAL-4	Consider how to assist local government in accessing federal funding for clean energy.	Unaddressed — The law does not direct technical or grant support for federal funding applications.
LOCAL-5	Consider developing GMA guidance on land conversion for clean energy projects, including for rural and resource lands.	Partially addressed in Section 307 — Commerce's rural clean energy report may inform this, but guidance is not required.
LOCAL-6	Update the Rural Element Guidebook.	Unaddressed — No mention of or requirement to revise the Rural Element Guidebook.
EE-3	Consider options for workforce development opportunities, including understanding workforce availability and opportunities for training, apprenticeships and high-quality jobs.	Partially addressed — The bill supports good jobs in intent, but does not fund or require workforce programs.

EE-4	Consider how to include labor standards, workforce agreements and local hiring provisions for clean energy projects.	Unaddressed — Labor agreements or standards are not required or incentivized.
EE-5	State agencies develop rural clean energy economy roadmaps in collaboration with local governments.	Partially addressed in Section 307 — Commerce must consult rural stakeholders and publish a rural energy report, but not a roadmap per se.
EE-6	Consider incentives to develop projects at sites identified through least-conflict studies or through planned actions or programmatic EISs to avoid or minimize impacts.	Partially addressed in Section 302(7) — Preferred zones may be designated in the future, but incentives are not included.
EE-8	Consider statutory change to strengthen requirements that communities receive benefits when new energy resources are developed.	Unaddressed — CBAs are voluntary; there's no statutory obligation to provide community benefits.
EE-9	Consider how to incentivize use of already developed industrial areas, infrastructure and brownfields, including opportunities to overcome financing barriers.	Unaddressed — No incentives or redevelopment tools for brownfield reuse are provided.
EE-10	Provide assistance to local governments related to documentation required for utilizing brownfield or Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) sites for clean energy projects.	Unaddressed — Technical assistance for brownfield reuse is not included.
EE-11	Provide funding and technical assistance for cleanup activities and reuse planning for siting on contaminated brownfields.	Unaddressed — No funds or grants are created for this purpose.
EE-12	Consider modifications or revisions to tax language to address different or concurrent uses of land, such as when land could be used for agricultural purposes and also for clean energy purposes.	Unaddressed — No tax provisions are updated or created.
EE-13	Consider developing guidelines for county assessors about how the income capitalization approach could be used to value clean energy facilities to avoid shifting tax burden due to depreciating assets.	Unaddressed — Tax assessment or valuation reform is not addressed.
EE-14	Develop information on tax incentive options for local government, developers and Tribes.	Unaddressed — No central incentive resource is created or mandated.
EE-15	Consider and explore financial tools for mitigating impacts of clean energy facilities.	Partially addressed — Section 206(8) allows mitigation through CBAs, but broader financial tools (e.g., impact fees) are not created.
PLAN-1	Conduct additional least-conflict mapping for specific geographic areas or energy types.	Partially addressed in Section 302 — Applies to solar only (WSU study); no requirement for other sectors or geographies.
PLAN-3	Provide funding for local governments, Tribes, agencies and communities for early planning.	Partially addressed — Tribes and stakeholders are consulted (302, 102), but no dedicated planning funds are provided.
PLAN-4	Develop guidance on how local governments can utilize least-conflict processes and upfront planning to provide information and reduce timelines for review and permitting of projects.	Unaddressed — No guidance or planning support tools provided to local governments.
ASSIST-1	State agencies should consider developing publicly accessible roadmaps for specific types of energy projects.	Unaddressed — No roadmaps or project-specific permitting timelines are developed.

ASSIST-2	Develop pre-application guidance for developers to consider when designing and siting clean energy projects.	Partially addressed in Sections 204–206 — Ecology’s initial assessment informs applicants, but no standard guidance is issued.
ASSIST-3	Provide greater clarity about state agency, local government, and Tribal government roles and responsibilities, and processes for making siting, review and permitting decisions.	Partially addressed — Roles are described in permitting sections (204–209), but no formal role summary or handbook exists.
ASSIST-4	Conduct internal process improvement analysis for state agency permitting processes.	Unaddressed — No agency evaluations or Lean/efficiency reviews are required.
ASSIST-5	Agencies should consider developing lessons learned for the public about the review and permitting processes for projects.	Unaddressed — No post-project analysis or reporting is mandated.
ASSIST-6	Develop guidance on the type of information needed for environmental reviews and permitting.	Partially addressed — Section 302 defines what nonproject reviews must include, but project-level requirements are not clarified.
ASSIST-7	Build state-level expertise on clean energy facilities and impacts to provide technical assistance for reviews and permitting.	Partially addressed in Sections 102 & 204 — Interagency council provides limited coordination, but technical expert roles not established.
ASSIST-8	Conduct studies and develop guidance to provide updated data and information for use by state agencies, local governments, Tribes and developers in environmental assessments.	Partially addressed in Section 302(3) — Requires impact and mitigation analysis, but no new studies are directly funded.
ASSIST-9	Develop tools to support consistent policies, standards and guidance on mitigation of impacts.	Partially addressed in Section 302(3)(b) — Mitigation must be identified in nonproject EISs, but no tools or frameworks are developed.
COORD-1	Develop landscape-level plan for federal lands that includes impact analysis and mitigation with state and federal agencies to be used for permitting of projects.	Unaddressed — No coordination or planning effort for federal lands is required in the bill.
COORD-3	Consider the development of standard MOUs or cooperative agreements to establish consistent federal and state coordination for environmental reviews.	Partially addressed in Section 206(3)(b)(i) — Ecology is tasked with inviting federal participation, but no template or MOU structure is mandated.
STATE-2	Develop a dashboard to provide one stop for information on proposed clean energy projects.	Unaddressed — No dashboard, tracking system, or project database is mentioned in the law.
STATE-3	Establish “clean energy navigators” at a state agency to provide guidance and expertise on state agency processes.	Partially addressed in Sections 204–206 — Ecology serves as lead coordinator, but no dedicated navigator role is created.
STATE-4	State agencies should assess current project-level interagency coordination for potential improvements to siting, environmental review and permitting roles and actions.	Unaddressed — No mandate for reviewing or reforming current coordination systems.
STATE-5	State agencies assess needs for staff dedicated to working on clean energy projects, planning and providing technical assistance.	Partially addressed in Section 102(3) — The council may recommend resource needs, but no formal capacity assessments required of agencies.