Pathway Case Studies: VT LCA

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Project Status

- Lifecycle analysis has been on pause to pursue engagement with experts in Traditional Ecological Knowledge (TEK) with the hope of weaving TEK components and data into the analysis
- Currently unable to find TEK experts to provide guidance, but will continue to pursue engagement to inform TEK scoping document as well as outside of this contract process
- With passage of Affordable Heat Act (S.5), ANR obligated to do a life-cycle analysis annually presenting an ongoing opportunity to learn and adapt our framework and develop additional supplemental analyses

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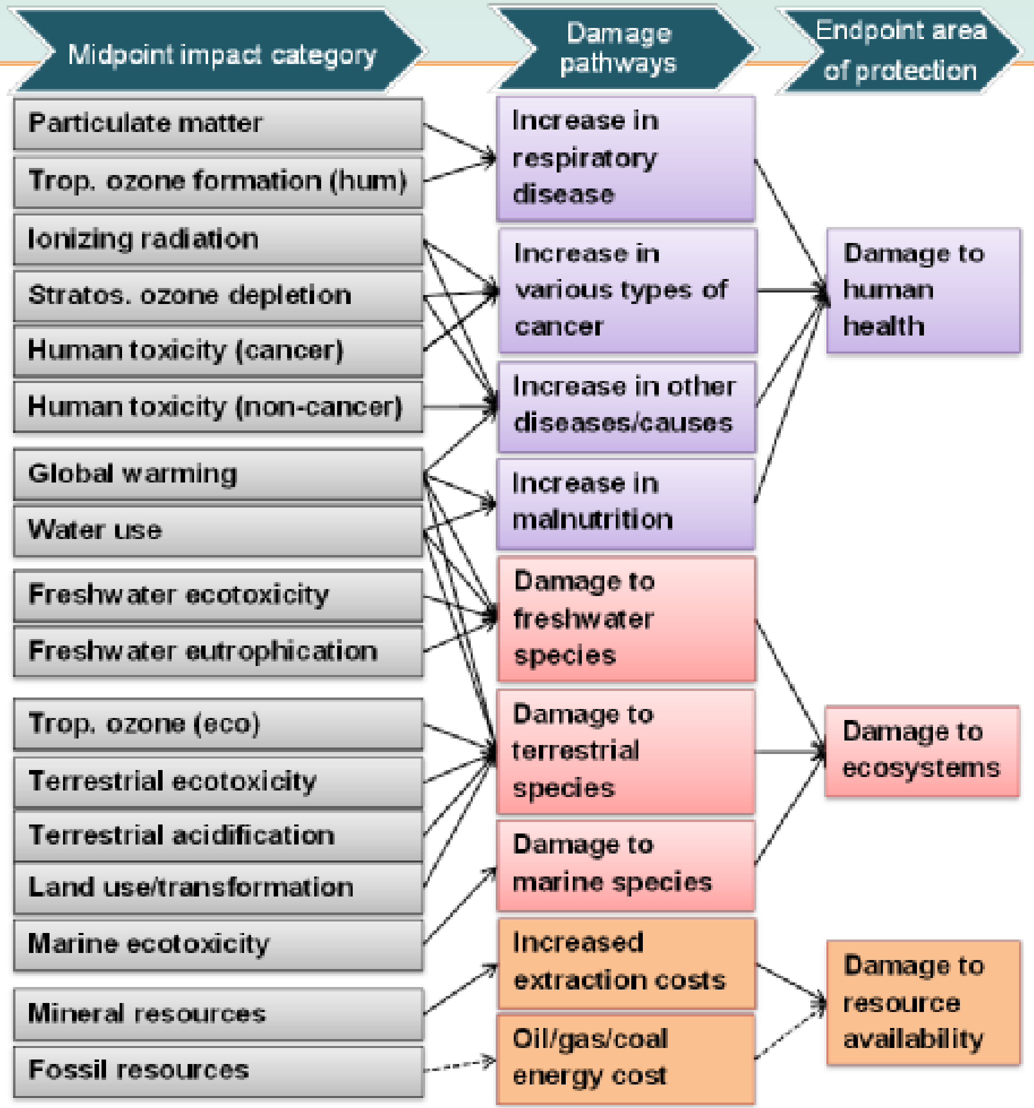
Primer Slide: GREET Refresher

- Using GREET to model VT energy commodities’ life cycle environmental impacts:
  - GHG Emissions
  - Air Pollutant Emissions
  - Total Energy Use
  - Water Use
- Previously covered inclusion/exclusion of energy pathways
- GREET does not contain other LCA impact categories

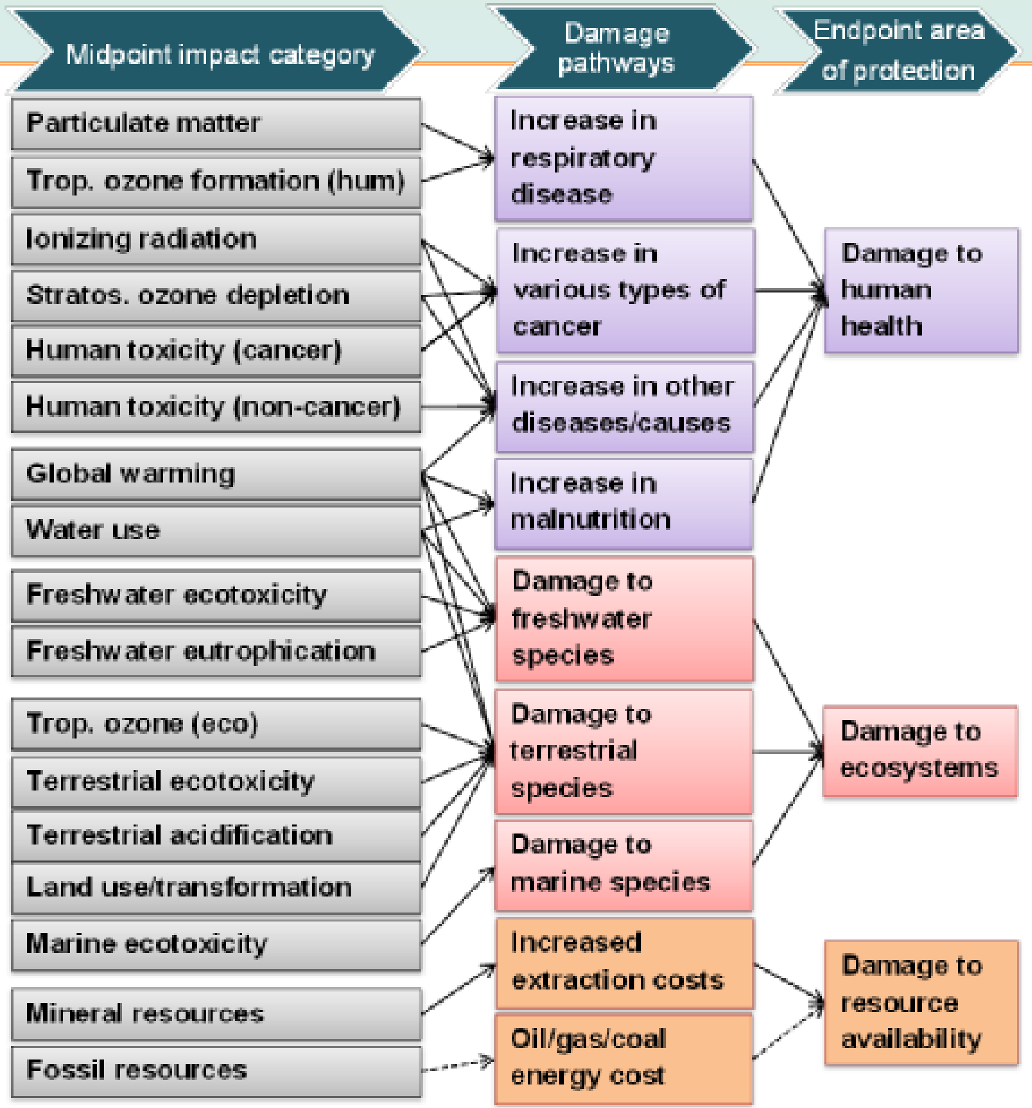


Source: [Figure 1.1, ReCiPe 2016 report]

Primer Slide: Questions to Consider

Stakeholder Input

- To which energy commodity model pathway(s) can I contribute my own knowledge and experience?
- What other impact(s) (in- and/or out-of-state) would you prioritize modeling?
- Consider TEK* integration with:
  - Forest carbon modeling & mgmt. frameworks
  - Direct + indirect land use change modeling
  - Ecotoxicity impact assessment methods



Source: Figure 1.1, ReCiPe 2016 report

*TEK: Traditional Ecological Knowledge; to-be-covered in later slides

Intro to LCA

- Objectives:
  - To inventory environmental inputs and outputs of a ‘system’ (to the fullest of a practitioner’s ability)
  - To associate the flows (ex. emissions) with externalities/impacts (ex. global warming, human health)
- LCAs are descriptive of modeled conditions*
  - Vermont project is only describing life cycle greenhouse gas impacts from current and historical energy use
  - Some emerging pathways, as they exist now, will also be modeled

*Credible LCAs conform to International Organization for Standardization (ISO) standards

Key Terminology

Goal: What is the objective of the LCA?

Scope: A clearly communicated definition of the system(s) being modeled

Energy Pathway: Any prevalent means by which energy is supplied for consumption

Life Cycle: Consecutive and interlinked stages of the energy pathway (ex. raw material, processing, production, transportation, consumption)

System Boundary: Defining the extent to which the life cycle is modeled (ex. only raw material extraction to production)

Life Cycle Inventory (LCI): All inputs (ex. raw or processed materials) and outputs (ex. emissions or products for consumption) required or released during life cycle stages

LCA Info Continued:

- Need to consider end-use when assessing energy pathways:
  - Ex. natural gas combusted for electricity vs. residential heating have different impact profiles
- All impact profiles, by energy pathway, should be comparable and based on a functional equivalence (ex. on a kg GHG/kWh basis)
  - Shared system boundary for assured comparability
    - Extraction → Processing → Transportation → Use → Disposal* → Treatment*

**Life cycle stages applicable only to certain energy pathways*

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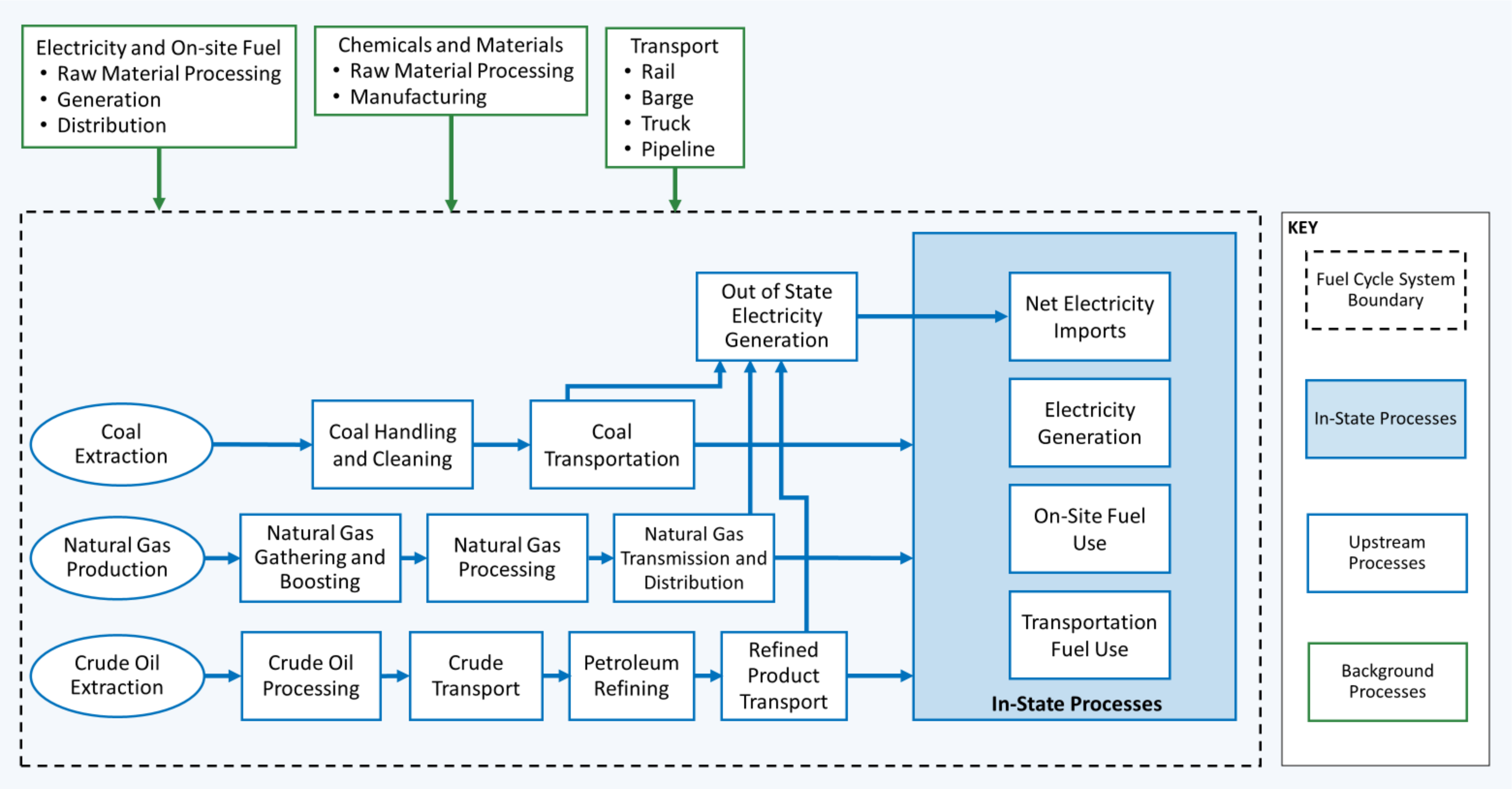
Defining the System Boundary



Pause for:

- Questions?
- Public Comment

Vermont Project Scope

- Vermont has already modeled emissions associated with in-state consumption of many energy pathways in the Vermont Greenhouse Gas Emissions Inventory and Forecast reports and the modeling completed for the Pathways report.
- ERG’s role is to
  1) model *out-of-state* (i.e. upstream) GHG impacts associated with modeled energy pathways; and
  2) model *in-state* consumption impacts for energy pathways not covered by original VT analysis
  3) Scale up total *in-state* and *out-of-state* based on total activities in the state

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LCA Representativeness

- Geographic, temporal, technological representativeness categories for LCA data
- Existing LCA/LCI data availability is influenced by the funding supporting their development, resulting in heterogenous representativeness
  - Some data are behind paywalls, or are not publicly available
    - Ex. Ecoinvent, GaBi, journal articles
  - We seek to maximize use of publicly available data in project
    - Ex. GREET, U.S. Life Cycle Inventory
- The impact profiles of some VT energy pathways are specific to biodiversity, soil/biomass carbon pools, land use/management in VT
  - VT-specific LCA data may not be available for all energy pathways
  - Several solutions to this problem (ex. customizing national data, assuming similar impact profiles from other existing data)

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Available Data

- Bottom-up / engineering models
  - Built from emission factor data and process models
- National datasets of reported emissions
  - e.g., EPA Greenhouse Gas Inventory, Greenhouse Gas Reporting Program
  - Combination of actual measured emissions and modeled estimates
- Gaps in locally-derived data can be supplemented with external sources
  - Modeled conditions may not match (ex. run-of-river hydroelectric emissions between Hydro Quebec & Vermont)

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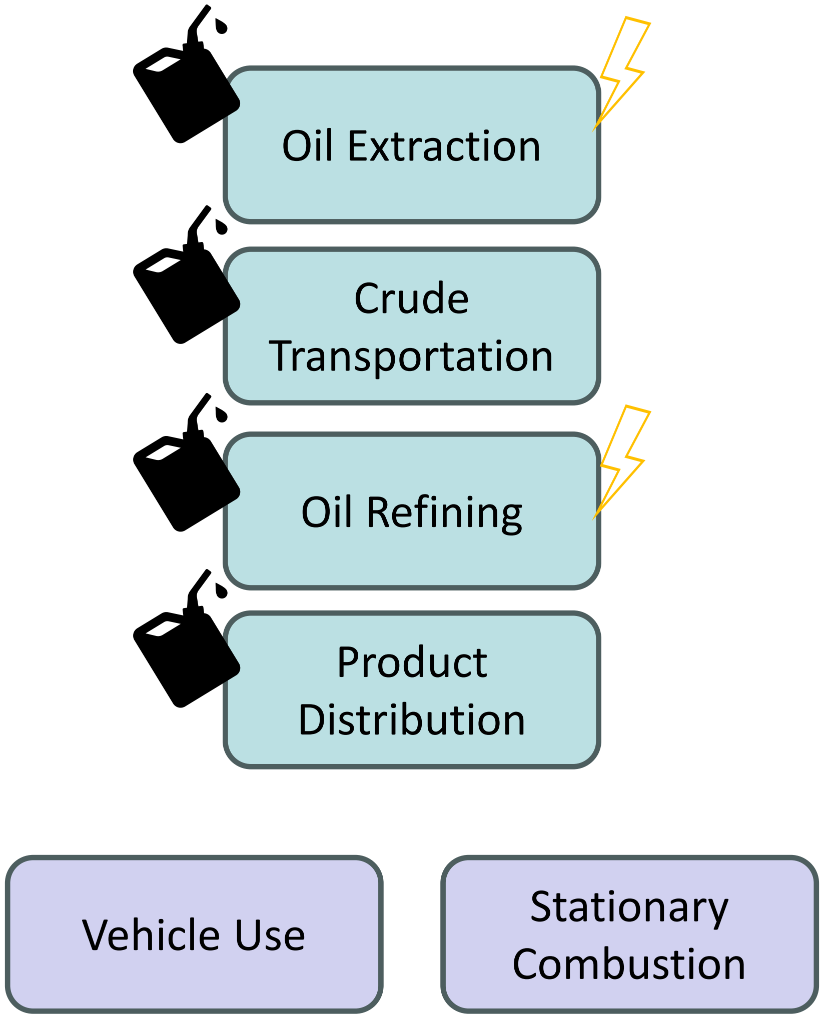
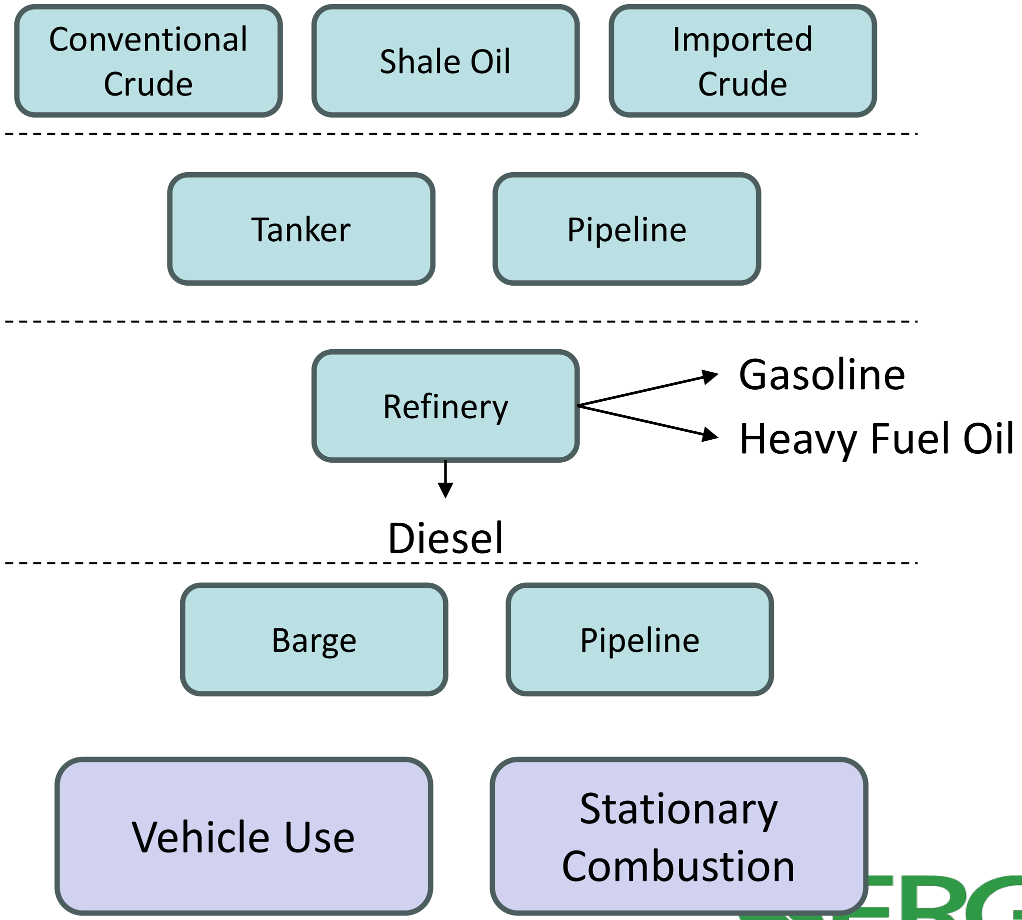
Pathway 1: Petroleum Fuels





Pathway 1: Petroleum Fuels – Crude Extraction

Petroleum to Gasoline, Liquefied Petroleum Gas, Residual Oil, Diesel, and Naphtha			
3) Calculations of Energy Consumption, Water Consumption, and Emissions for Petrole			
	Crude Oil		
	Recovery	Transportation to U.S. Refineries	Storage
Energy efficiency	98.0%		
Loss factor		1.000	1.000
Energy ratio of crude oil feeds to product (mmBtu of crude/mmBtu of fuel throughput)			
Crude oil / SCO	1.0%		
Residual oil	1.0%		
Diesel fuel	15.0%		
Gasoline	2.0%		
Natural gas	61.9%		
Coal	0.0%		
Liquefied petroleum gas			
Electricity	19.0%		
Hydrogen	0.0%		
Pet coke			
Butane			

	Crude Oil		
	Recovery	Transportation to U.S. Refineries	Storage
Total energy	30,480	14,480	0
Fossil fuels	28,792	12,398	0
Coal	2,872	3,541	0
Natural gas	21,748	4,704	0
Petroleum	4,172	4,153	0
Water consumption	20.346	0.918	0.000
Total emissions: grams/mmBtu of fuel throughput			
VOC	1.321	0.259	
CO	6.397	0.993	
NOx	6.746	5.198	
PM10	0.228	0.402	
PM2.5	0.181	0.345	
SOx	0.636	2.654	
BC	0.047	0.048	
OC	0.056	0.130	
CH4: combustion	6.794	1.725	
N2O	0.035	0.021	
CO2	2,747	968	
VOC from bulk terminal	0.702	1.534	
VOC from ref. Station	1,083	CO2 emissions from associated	
CH4: non-combustion	80.000	gas flaring and venting	

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Pathway 2: Renewable Natural Gas (RNG) from Animal Waste

Source: https://vanguardrenewables.com/projects/goodrich-family-farm

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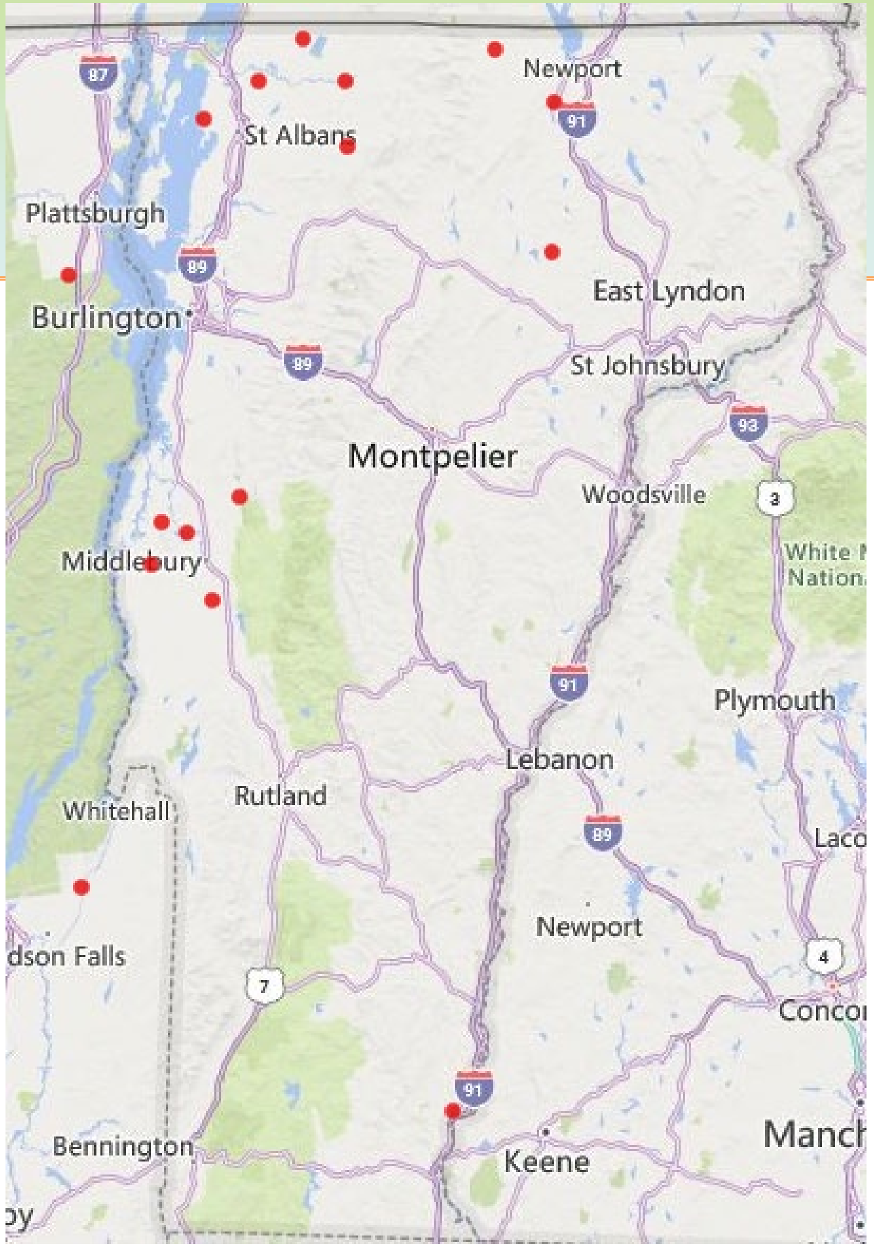
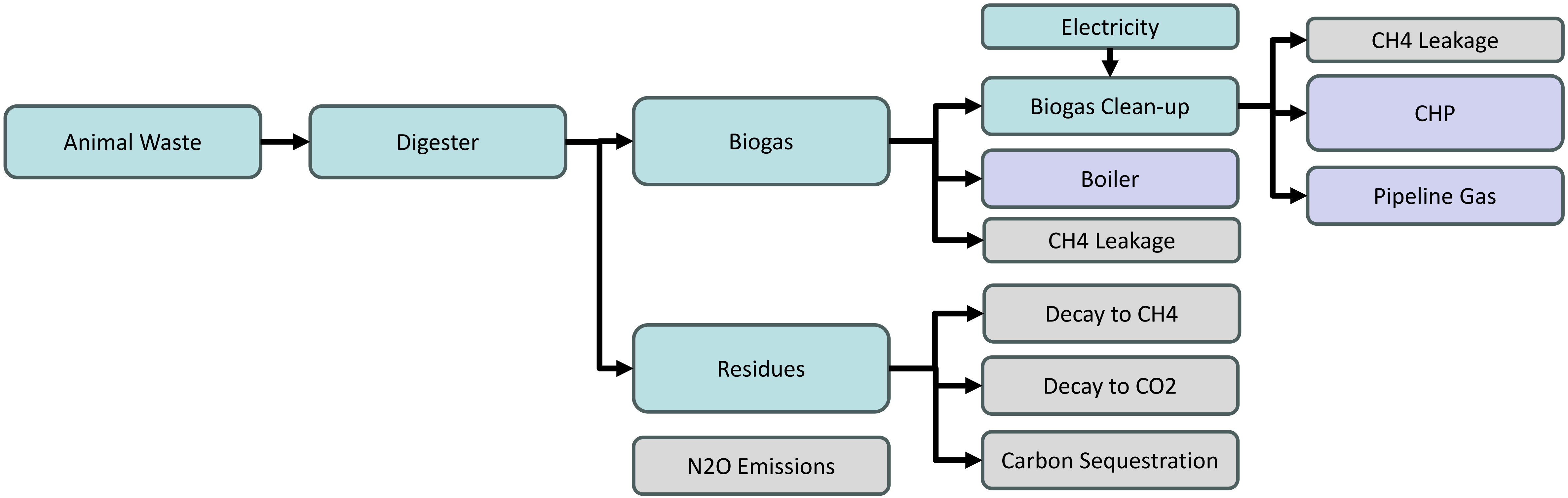
EPA & USDA AgSTAR Data

- VT has 14 digesters on dairy farms
  – Many new projects seeking permits & approvals
- Feedstocks: cow manure, food & dairy processing wastes (e.g., spoiled product), agricultural residues
- End uses:
  – Co-generation (a.k.a. CHP): ~25 GWh electricity per year generated by farms + utilities
  – Pipeline gas: e.g., sent to Vermont Gas
  – Boiler/furnace fuel: consumed on-site
- AgSTAR accuracy limited since "data are compiled from a variety of voluntary sources" [ref]



Source: USDA AgSTAR

Pathway 2: Animal Waste RNG



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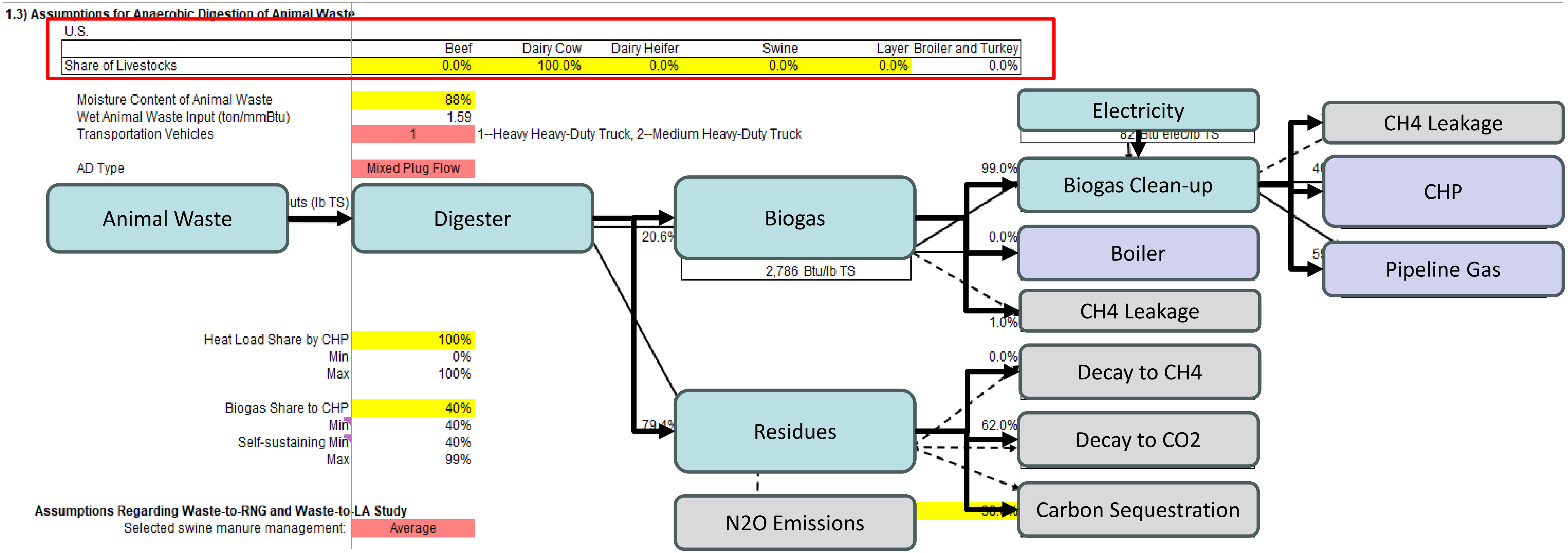

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Pathway 2: Animal Waste RNG

Project Name	Project Type	City	County	State	Digester Type	Year Operational	Animal/ Farm Type(s)	Cattle	Dairy	Poultry	Swine	Co-Digestion	Biogas Generation Estimate (cu-ft/day)	Electricity Generated (kWh/yr)	Biogas End Use(s)
Blue Spruce Farm, Inc. / Audet's Cow Power Digester	Farm Scale	Bridport	Addison	VT	Mixed Plug Flow	2005	Dairy		3,900			Dairy Processing Wastes		4,204,800	Cogeneration
Chaput Family Farms Digester	Farm Scale	North Troy	Orleans	VT	Complete Mix	2010	Dairy		1,700			Food Processing Wastes; Process Water	111,114	1,600,000	Cogeneration
Dubois Farm Digester	Farm Scale	Vergennes	Addison	VT	Mixed Plug Flow	2010	Dairy		1,200					2,700,000	Cogeneration
Four Hills Farm Digester	Farm Scale	Bristol	Addison	VT	Mixed Plug Flow	2012	Dairy		1,200					3,350,700	Cogeneration
Gervais Family Farm Digester	Farm Scale	Bakersfield	Franklin	VT	Mixed Plug Flow	2009	Dairy		950			Dairy Processing Wastes		780,000	Cogeneration
Goodrich Family Farm Digester	Farm Scale	Salisbury	Addison	VT	Complete Mix	2021	Dairy		900			Food Wastes	383,562		Pipeline Gas
Green Mountain Dairy, LLC Digester	Farm Scale	Sheldon	Frankin	VT	Mixed Plug Flow	2007	Dairy		1,050			Dairy Processing Wastes	115,500	1,800,000	Cogeneration
Jasper Hill Farm Digester	Farm Scale	Greensboro	Orleans	VT	Mixed Plug Flow	2014	Dairy		45			Dairy Processing Wastes; Other Feedstocks			Boiler/Furnace fuel
Kane's Scenic River Farms Digester	Farm Scale	Enosburg Falls	Franklin	VT	Mixed Plug Flow	2011	Dairy		850					1,675,350	Cogeneration
Maxwell Farm / Neighborhood Energy, LLC Digester	Farm Scale	Coventry	Orleans	VT	Mixed Plug Flow	2008	Dairy		750			Food Processing Wastes		1,750,000	Cogeneration
Monument Farms Digester	Farm Scale	Weybridge	Addison	VT	Mixed Plug Flow	2011	Dairy		500			Dairy Processing Wastes; Food Processing Wastes		788,400	Cogeneration
Nelson Boys Dairy, LLC Digester	Farm Scale	Swanton	Franklin	VT	Mixed Plug Flow	2007	Dairy		1,200				132,000	1,400,000	Cogeneration
Pleasant Valley Farms - Berkshire Cow Power, LLC Digester	Farm Scale	Berkshire	Franklin	VT	Mixed Plug Flow	2006	Dairy		1,950			Dairy Processing Wastes	220,000	3,500,000	Cogeneration
Westminster Farms Digester	Farm Scale	Putney	Windham	VT	Mixed Plug Flow	2009	Dairy		1,200			Agricultural Residues; Food Processing Wastes		1,642,500	Cogeneration
													TOTAL:	25,191,750	

Pause for:

- Questions?
- Public Comment

Integrating Traditional Ecological Knowledge

- TEK *(also called Indigenous Knowledge, Native Science)* refers to:
  - On-going accumulation of knowledge, practice and belief about relationships between living beings in a specific ecosystem.
  - Acquired by indigenous and local people over hundreds or thousands of years through direct contact with the environment, handed down through generations, and used for life-sustaining ways.
  - Knowledge specific to a location and includes the relationships between plants, animals, natural phenomena, landscapes and timing of events that are used for lifeways, including but not limited to hunting, fishing, trapping, agriculture, and forestry.
  - It encompasses the world view of indigenous people which includes ecology, spirituality, human and animal relationships, and more.

- National Park Service

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Integrating TEK: Aim and Approach

- Original Aim: Incorporate TEK perspectives into the analysis
  - Input on selected energy pathways
  - Considerations for interpreting study findings
  - Considerations for future work via a scoping document
- Met with VT State Team and select LCA task group members to determine approach

Identify 1-2 Experts to Inform Engagement → Hold Conversation with Initial Experts to Discuss TEK Engagement Process → Develop TEK Engagement Process Based on Expert Input → Identify TEK Engagement Participants → Conduct TEK Engagement

Integrating TEK: Expert Identification & Outreach

- Sought experts:
  - Working at nexus of traditional/western science and TEK
  - Prior experience integrating TEK in traditional/western science analyses
- Outreach to initial experts has not been successful
  - Limited number of individuals with desired expertise
  - Individuals contacted expressed that they are not a good fit
  - Some who might be appropriate have not been able/willing to participate
- Will continue to pursue outside expert input to incorporate into ongoing LCA work

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Integrating TEK: Moving Forward

- Moving forward
  - Identify opportunities/areas in the analysis where TEK input could be integrated through task group input
  - Develop scoping document for how TEK might be integrated into future LCA-based analyses at end of current project phase and/or as additional analyses or investigations to inform energy pathway choices in conjunction with the results of LCA analyses
    - Opportunities in scenario analysis and decision making
    - Motivations for locally-oriented life cycle inventory data development
  - Integrate TEK engagement into forthcoming/ongoing LCA work

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TEK Discussion

- What role should TEK play in Vermont's LCA work?
  - Particularly with historical modeling
- What opportunities do you see to combine LCA data with TEK principles?
- Are there any considerations for the development of the scoping document that you would like to share?
  - What additional factors should be considered, either within or outside of the TEK discussion – e.g., biodiversity, socioeconomic impacts, etc.

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Questions?