Spatial Informatics Group

2529 Yolanda Court
Pleasanton, CA 94566
(510) 427-3571
Sig-gis.com

Scope of Work:

Greenhouse Gas Life Cycle Assessment for Medium-Density Fiber Board produced from a variety of feedstocks in Marysville, CA

Project report to:

West Forest LLC

Points of contact:

Scott Gable, e: scott.tk.gable@gmail.com

Prepared on behalf of Spatial Informatics Group LLC (SIG) by:

Thomas Buchholz, PhD, Senior Scientist (project lead and carbon accounting)
c: 802 881 5590, e: tbuchholz@sig-gis.com

Liz Luck, MSc, Research Scientist (data processing)

David Schmidt, MSc, Research Scientist (wildfire modeling)

Date:

March 22, 2024

CONTENTS

1 RATIONALE.......... 1

2 METHODS.......... 2

2.1 FEEDSTOCK LCA.......... 2

2.1.1 LCA accounting framework.......... 2

2.1.2 Assessment boundaries and functional unit.......... 3

2.2 SPREADSHEET DEVELOPMENT.......... 4

2.3 FEEDSTOCK ANALYSIS.......... 4

2.3.1 Timber Harvest Residuals.......... 4

2.3.2 Sawmill Residuals.......... 5

2.3.3 Forest Fuels Reduction Residuals.......... 6

2.3.4 Urban Wood.......... 13

2.3.5 Agricultural Byproducts.......... 14

2.4 CONSEQUENTIAL GHG LCA – GHG EMISSIONS FROM TRANSPORT.......... 14

3 SUMMARY OF RESULTS.......... 15

REFERENCES.......... 17

APPENDIX A- FVS TREATMENT KCP.......... 18

1 RATIONALE

West Forest LLC is developing a medium density fiber (MDF) board production facility in California in the city of Marysville. West Forest is interested in a greenhouse gas life cycle assessment (GHG LCA) of MDF.

Wood products store carbon when used for buildings or other uses. The manufacture of these products using carbon neutral wood residuals result in biogenic and fossil fuel carbon flows over time. Spatial Informatics Group LLC (SIG) completed a GHG LCA for a range of feedstocks for MDF production following conventional LCA standards for attributional GHG LCAs. By producing a spreadsheet for interactive scenario exploration, SIG examined the net effects that MDF production would have on GHG emissions when a MDF mill of average production parameters would be either in active operation, or absent (section 2.3). A consequential LCA element was also considered examining the transport emissions saved when producing MDF locally for the CA market instead of domestic (western US) or international shipping.

The timber supply radius for the Marysville production considered was up to 100 miles around the city of Marysville (average transport distance differed by feedstock type – see assumptions in the Excel spreadsheet tool).

The following feedstock sources were considered:

- Timber Harvest Residuals: non-sawlog bole sections from commercial timber harvest projects on industrial private timberlands;
- Sawmill Residuals: sawdust, chips, and shavings;
- Forest Fuels Reduction Residuals: non-sawlog bole sections removed during pre-commercial thinning harvest on Forest Service lands;
- Urban Wood: chipped woody biomass from urban tree care and removal operations;
- Agricultural Byproducts: chipped woody biomass from commercial orchard removals.

In a second step, a consequential GHG LCA analysis framework provides opportunities to explore scenarios in terms of their GHG impact where MDF produced at Marysville is being compared to MDF produced domestically or imported (section 2.4).

2 METHODS

2.1 Feedstock LCA

2.1.1 LCA accounting framework

The approach to a GHG LCA is based on the ISO 14040 and 14044 methodologies (ISO, 2006a, 2006b). An LCA addresses the environmental aspects and potential environmental impacts, (e.g., use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e., cradle-to-grave). There are two basic approaches to LCA:

- Attributional LCAs seek to establish the burdens associated with the production and use of a product, or with a specific service or process, at a point in time (typically the recent past);
- Consequential LCAs seek to identify the environmental consequences of a decision or a proposed change in a system under study (regulations, policies, carbon offsets).

According to the ISO standards, an LCA is an iterative process for tool development and merges science (knowledge production) with policy negotiations (norm creation). This process is outlined in Figure 1 and contains four phases:

- **Goal and scope definition phase.** The scope, including system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA.
- **Inventory analysis phase (LCI).** Inventory of input/output data with regard to the system being studied. It involves the collection of the data necessary to meet the goals of the defined study.
- **Impact assessment phase (LCIA).** Provide additional information to help assess a product system's LCI results so as to better understand their environmental significance. LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.
- **Interpretation phase.** Results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

ISO provides a framework for LCA studies but there is no single method for conducting an LCA. There is large flexibility when performing an LCA under ISO based on the intended application and needs. Therefore, the ISO 14040 framework (2006a) stresses that:

> *"LCA addresses potential environmental impacts; LCA does not predict absolute or precise environmental impacts due to:*

- the relative expression of potential environmental impacts to a reference unit,
- the integration of environmental data over space and time,

- the inherent uncertainty in modelling of environmental impacts, and
- the fact that some possible environmental impacts are clearly future impacts;”

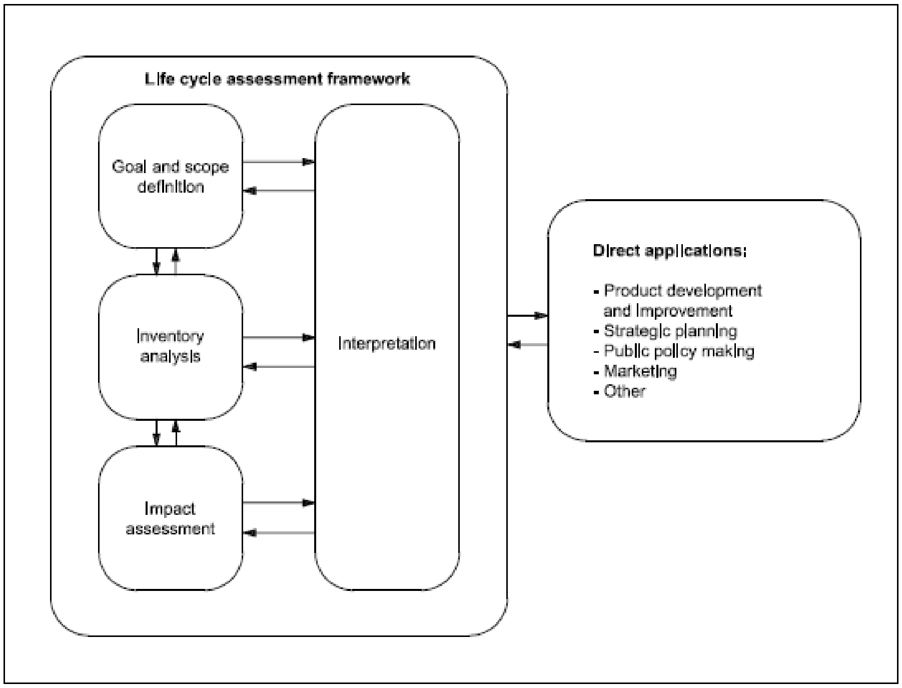

Figure 1: LCA phases (ISO, 2006a).

2.1.2 Assessment boundaries and functional unit

Unless noted otherwise in the specific technology pathways described below, the following assessment boundaries apply:

- GHG emissions considered were restricted to emissions associated with the **production process and operations** itself as well as the in-use and post-use fate of the product. Emissions from construction and material maintenance/decommissioning were considered out of scope;
- The spatial boundaries differed by pathway based on available information and are described in the relevant feedstock sections below. The temporal boundary was restricted to a 40-year horizon including forest growth and wildfire dynamics (section 2.3.3 Forest Fuels Reduction Residuals) as well as biomass decay and residence times of MDF products;
- The assessed impact category was **climate impact**, and wherever possible, included carbon dioxide (CO_2), methane (CH_4) and Nitrous oxide (N_2O) emissions (e.g., transport GHG emissions from fossil fuel use). For the avoided wildfire emissions accounting, this also included fine particulate matter ($PM_{2.5}$);

- The functional unit in an LCA provides the ultimate unit to report results and compare the (GHG) impact of different choices as explored in a consequential LCA. The functional unit in this context is metric tonnes (or MT) of carbon dioxide equivalents (**MT CO_2e**) for the entire system analyzed with a time horizon of 40 years for GHG-relevant activity impacts. This functional unit allows to also consider non-CO_2 emissions (e.g., methane, nitrous oxide) in its impact analysis which can be cross walked into CO_2e through an established value that defines the global warming potential (GWP) relative to CO_2. This GWP considers both radiative forcing and longevity/temporal residence time functions in the atmosphere as it might differ compared to CO_2.
- Some GHG impact categories, while quantifiable, fall under a ‘de minimis’ approach or rule where the lack of overall significance of a given impact category for the overall GHG assessment does not merit the effort involved. The impact would be so minor as to merit disregard.

2.2 Spreadsheet development

We created an Excel spreadsheet-based tool that provides for an interactive scenario analysis for different feedstock types, feedstock mixes. This tool also allows for scenario analysis on transport profiles for MDF produced domestically or internationally to allow for a GHG impact comparison (by transport emissions) to Marysville-based MDF production. All assumptions and data inputs are documented in the tool (West Forest GHG LCA_date.xlsx).

Key results are reported in the ‘Coversheet’ tab with specific GHG profiles by feedstock mix (attributional LCA; ‘Outputs I’ in row 21 and following), transport emission profiles (consequential LCA; ‘Outputs II’ in row 23 and following) and a combination of Outputs I and II (‘Outputs III; row 31 and following).

2.3 Feedstock analysis

2.3.1 Timber Harvest Residuals

Timber harvest residuals would be sourced on private industrial timberlands from commercial harvests (Figure 2). Only boles are considered as a feedstock not meeting sawlog quality standards. In the absence of the Marysville MDF plant, these boles would be pile-burnt and/or left on site for decay (baseline). The ‘West Forest GHG LCA_date.xlsx’ spreadsheet tool specifies and documents all input and conceptual assumptions in detail (tab ’timber harv.res.').

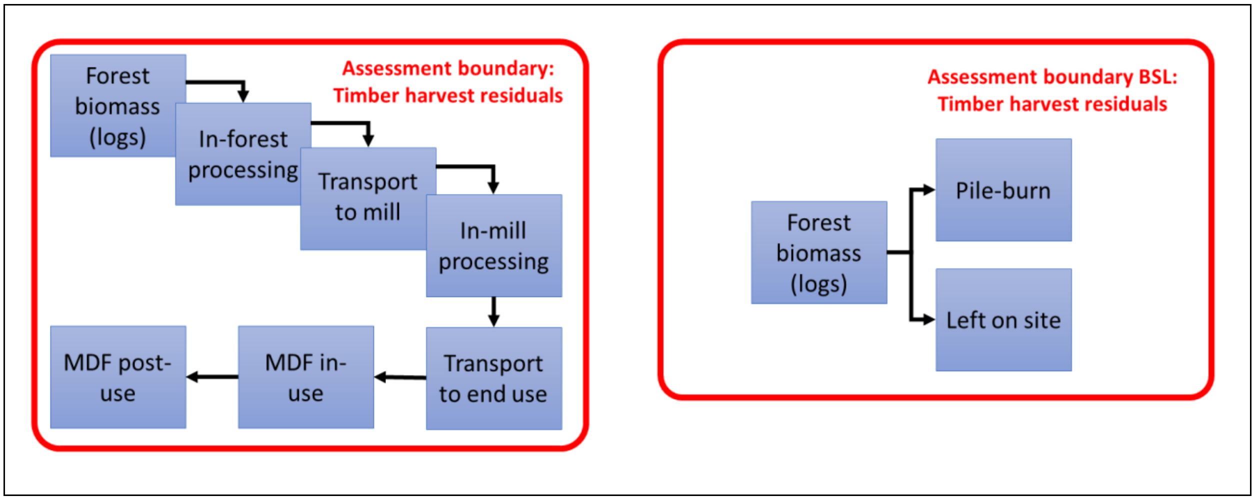

Figure 2: Analytical boundary for timber harvest residuals and associated baseline assumptions.

2.3.2 Sawmill Residuals

Sawmill residuals would be sourced from nearby sawmills. We explored the impact of two sawmill residual scenarios that differed in the baseline assumptions. In the first scenario (tab ’Sawmill res. I'), sawmill residuals would be utilized for electricity generation and/or bedding material/nurseries under a baseline assumption (Figure 3).

In the second scenario (tab ’Sawmill res. II'), sawmill residuals would be utilized for MDF production. However, to avoid a drop in biomass-based electricity production through the competition for feedstock (MDF production vs. electricity production), agricultural byproducts such as orchard removals would be shipped to electricity generating bioenergy plants. In the absence of the Marysville MDF plant, these agricultural byproducts would be pile burnt (Figure 4). The ‘West Forest GHG LCA_date.xlsx’ spreadsheet tool specifies and documents all input and conceptual assumptions in detail.

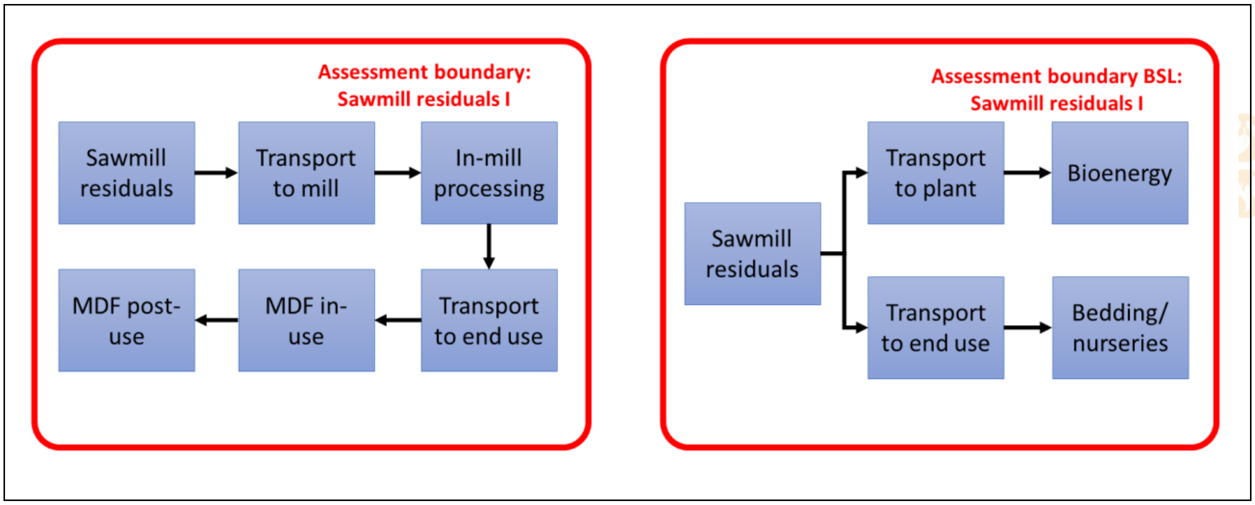

Figure 3: Analytical boundary for sawmill residuals (baseline I) and associated baseline assumptions.

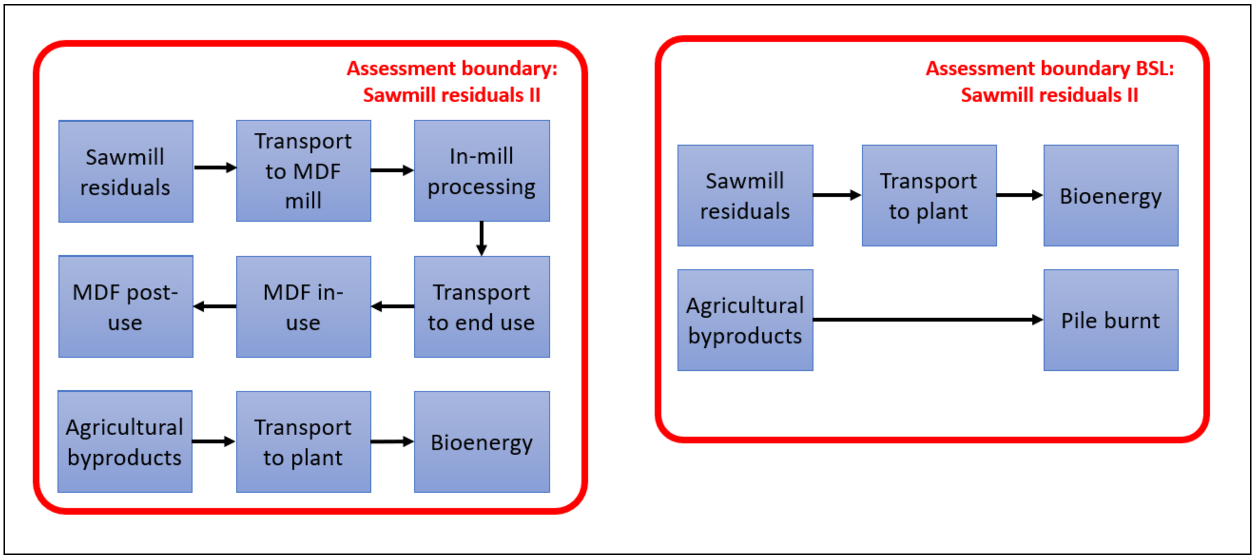

Figure 4: Analytical boundary for sawmill residuals (baseline II) and associated baseline assumptions.

2.3.3 Forest Fuels Reduction Residuals

Production of MDF wood at the Marysville production facility requires 82,500 Bone Dry Short Tons (BDT; equaling around 75,000 metric tonnes) of forest fuel reduction residuals. The forest fuels reduction accounts for small logs produced as a byproduct of fuels reduction activities. This forest biomass is made up of small stems not meeting sawlog quality criteria or being too dispersed to allow for effective transport to sawmills.

Factors that are considered in the GHG LCA of the forest fuels reduction residuals supply are the carbon cycle in the presence of harvests to serve the mill including wildfire dynamics. This includes the direct removal of potential wildfire fuels and the indirect results of creating more wildfire resilient forest ecosystems.

Forest fuel reduction residuals would be sourced on federal forests from non-commercial harvests (Figure 5). This feedstock was assessed against two different baseline scenarios. For both scenarios, we ran a full avoided wildfire emissions (AWE) analysis (see below for details). The first baseline scenario assumed that no fuel treatments would take place. GHG emission dynamics were assessed with the treatments implemented vs. not-implemented (BSL I: no fuel treatments). The second baseline scenario assumed that fuel treatments would be implemented regardless of the Marysville plant but residuals would be pile-burnt or left on site (BSL II: Fuel treatments). Wildfire behavior would differ between all three scenarios (MDF production; BSL I, BSL II) and was analyzed accordingly. Besides a methodological description for AWE modeling below, the ‘West Forest GHG LCA_date.xlsx’ spreadsheet tool specifies and documents all input and conceptual assumptions in detail (tab ’Fuel treatments').

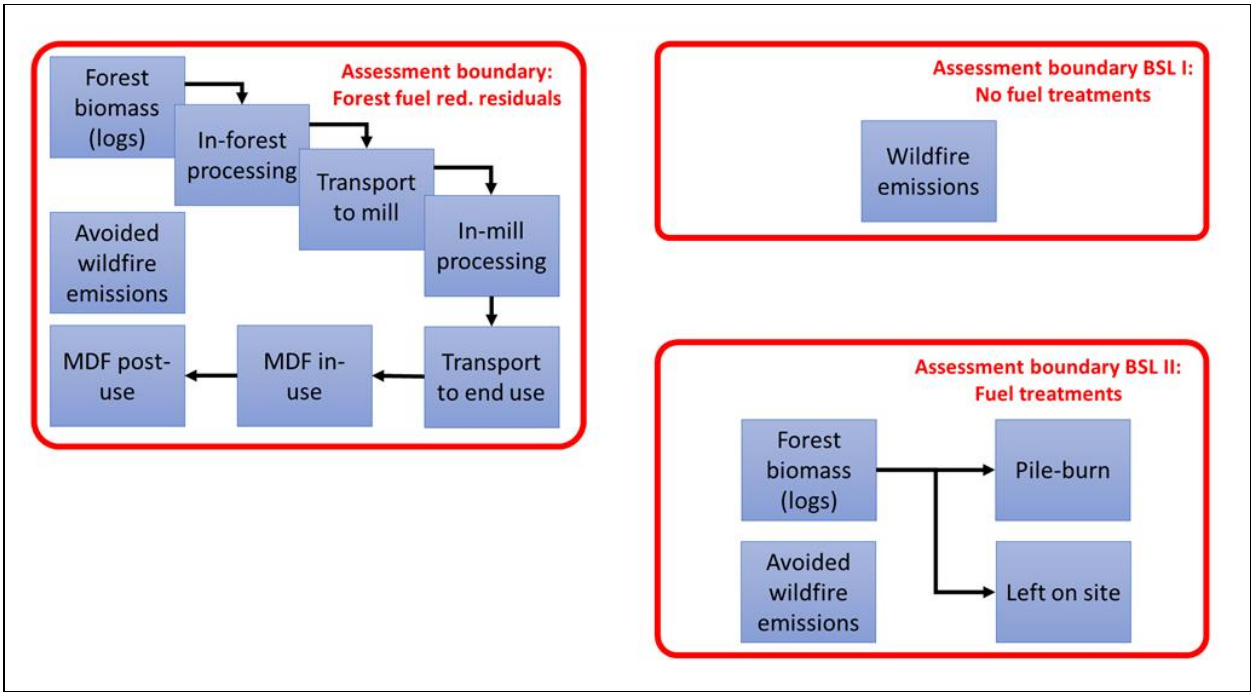

Figure 5: Analytical boundary for forest fuel reduction residuals and associated baseline assumptions.

Modeling avoided wildfire emissions (AWE)

SIG built a semi-automated Forest Carbon Accounting Tool (FCAT) which is a command-line tool designed to gauge the potential for mitigating greenhouse gas emissions through fuel treatments. All data sources and models used by FCAT are in the public domain. In its entirety, FCAT employs the methodology for calculating AWE as specified under the Reduced Emissions from Megafires (REM) framework which in turn enables listing of fuel treatments in the carbon market under Climate Forward, a sub-platform of the Climate Action Reserve’s registry[1]. FCAT employs forest growth, carbon flux, and fire behavior simulations based on pixel-based measurements of vegetation type, structure, and wildland fuels. Its components encompass GIS processing, Forest Vegetation Simulator (FVS) modeling for forest growth, fuel treatments, and GridFire Monte Carlo wildfire behavior simulations, First Order Fire Effects Model (FOFEM; Lutes, 2016) smoke emission estimates, and carbon quantification. FCAT's adaptability allows these components to serve as microservices to support the tasks in this scope of work and for various projects beyond GHG mitigation assessment alone.

The FCAT Modeling Process consists of a series of semi-automated microservices:

1. GIS pre-processing to prepare the area of interest (AOI), baseline (e.g., let grow) and project conditions (e.g., implementing fuel treatments), as well as disturbances (e.g.,

---

[1] https://climateforward.org/program/methodologies/reduced-emissions-from-megafires/

burn scars). The only project-specific data input required in this context are treatment locations and prescriptions while all other inputs (e.g., vegetation and climate data, burn probabilities) are lookup based or derived from datasets in the public domain.

2. Identify every unique combination from TreeMap ID, past disturbance, and future treatment rasters.
3. Build an USFS Forest Vegetation Simulator (FVS) input database:
    a) Each unique combination is simulated as an individual forest stand,
    b) Instructions are embedded for simulating disturbances and treatments.
4. Execute FVS:
    a) R script to automate building and executing FVS keyfiles for various FVS simulations in 5-year time steps over a 40-year time horizon,
    b) FVS post-processing,
    c) Compute the acreage represented by each FVS stand.
5. USFS First Order Fire Effects Model (FOFEM):
    a) Automate data formatting and execution of FOFEM.
6. Run Pyregence's GridFire Simulations:
    a) Automate data setup and execution of GridFire,
    b) Calculate conditional burn probability (CBP) ratio for each stand.
7. Final processing to produce carbon tables including GHG impacts, carbon stock trajectories, biomass removed, etc.

With this process SIG can:

- Efficiently update TreeMap vegetation inventory data to current year with rFVS,
- Update the initial spatial fuels data going into FVS and GridFire with FireFactor methods (and eventually FuelsMap data),
- Run rFVS at full TreeMap resolution (30-m pixels) on large areas (possibly unprecedented),
- Simulate virtually any disturbance, management, or fuels treatment at any point in the future,
- Run virtually any AOI on demand and into the future as far as needed,
- Query data on carbon, forest stand, fire behavior, fire effects, and emissions data with and without treatments at every timestep.

Conceptually, FCAT implements the following five steps:

Step 1. Project area. Define the geographic boundary of the project. Quantify the forest condition - including tree stands, tree list, species, height, and diameter, and surface fuels - in the project area existing at the start of the project through site characterization measurements. Define weather conditions under which to simulate fire over the project term.

For project-specific landscape-level and AWE accounting, we use the 2016 TreeMap tree list from the Missoula Fire Lab (TreeMap; Riley et al., 2019). The TreeMap dataset has been also approved by the California Air Resources Board for carbon modeling in support of applications for funding from the State's Greenhouse Gas Reduction Fund. The TreeMap dataset is a 30-m interpolated raster map that covers the entire contiguous United States and can be used to explore tree-level data as of 2016. We simulate disturbances such as wildfires and timber harvests that occurred between 2017 and 2022 with FVS to update the tree inventory to current conditions.

Step 2. Management scenario development. Define the details of the fuel treatment - including fuel reduction harvesting levels, procedures, location, timing, and fate of residuals.

In collaboration with West Forest LLC and TSS, we identify fuel treatment locations, types and schedules to be modeled.

Step 3. Forest carbon and Forest removals life cycle assessment. Project the growth of the forested land over the project term (40 years) at five-year intervals. Determine sequestration in wood products, and avoided/displaced fossil fuels from wood products and bioenergy.

We project the carbon stocks and flows of the forested land over the project term (40 years) at five-year intervals. Live above ground, live below ground, and dead and down wood will be estimated for the baseline (no treatments) and fuel treatment scenarios using models of forest management across the full project term. Modeling of forest growth is completed using the regional variant of the Forest Vegetation Simulator Fire and Fuels Extension (FVS-FFE; Rebain et al., 2022). FVS-FFE calculates and tracks carbon in the following pools: total aboveground live which includes merchantable and un-merchantable live stems, branches, and foliage; standing dead; understory (shrub and herbaceous layers); forest floor (litter and duff); forest down dead wood; belowground live roots and belowground dead roots. FVS-FFE outputs include projected volume in live aboveground tree biomass and (wildfire) emission by appropriate strata in the baseline scenario. FVS-FFE outputs will be used to also account for non-CO_2 GHG emissions (e.g., N_20, CO, CH_4) in the FOFEM model. The baseline FVS simulations assuming no project implementation include all stands but no treatments would be simulated (BSL I) or biomass would be left in the forest (BSL II).

Step 4. Wildfire modeling and emissions. Determine emissions from wildfire that burns the entire project area, at five-year intervals over the project term. Amortize the emissions by the statistical fire probability.

We run a fire behavior model such as GridFire[2] to determine a change in fire spread due to fuel treatments in order to also capture GHG benefits from a change in wildfire behavior in non-treated forested stands ('wildfire shadow effect'). For this project the landscape was very large and the GridFire simulations were running slowly so we opted to bypass GridFire and assumed there was no indirect effects. Typically, these account for a small portion of overall GHG emissions and meet de minimis accounting requirements (<5% variance in results). Therefore, so our results are considered to be a conservative GHG emission estimate.

Step 5. Aggregated emissions accounting. Determine the difference between the baseline and project scenario GHG emissions, for each five-year interval period over the project term.

In a last AWE/REM- related step, we consider GHG flux consequences if high-severity wildfire occurrence decreases due to fuel treatments and a reduced acreage of stands would experience prolonged time scales of delayed regeneration (temporary or permanent vegetation type change from forests to grass or shrub dominated landscape) and therefore exhibit a forgone carbon sequestration potential. Wildfire related emissions are discounted by the area's expected statistical fire probability over the project term. The final result are net climate impacts when implementing fuel treatments measured in metric tonnes of CO_2e for the entire forested fireshed.

GIS preprocessing

In order to create the supply radius, we used the city of Marysville boundary and created a buffer of 100 miles. Ownership shapefiles from CAL Fire GIS were intersected in this area and we assumed BLM (500,000 acres) and USFS land (4.5 million acres) are the public lands where the forest fuels reduction residuals are derived (Figure 6). The selected public lands within the 100-mile radius (with the assumption that the average transport distance to the mill would be around 75 miles) were then run through FCAT to determine a baseline of carbon within the stands and found 54,188 stands on 3,584,162 forested acres of federal public lands.

---

[2] https://github.com/pyregence/gridfire/

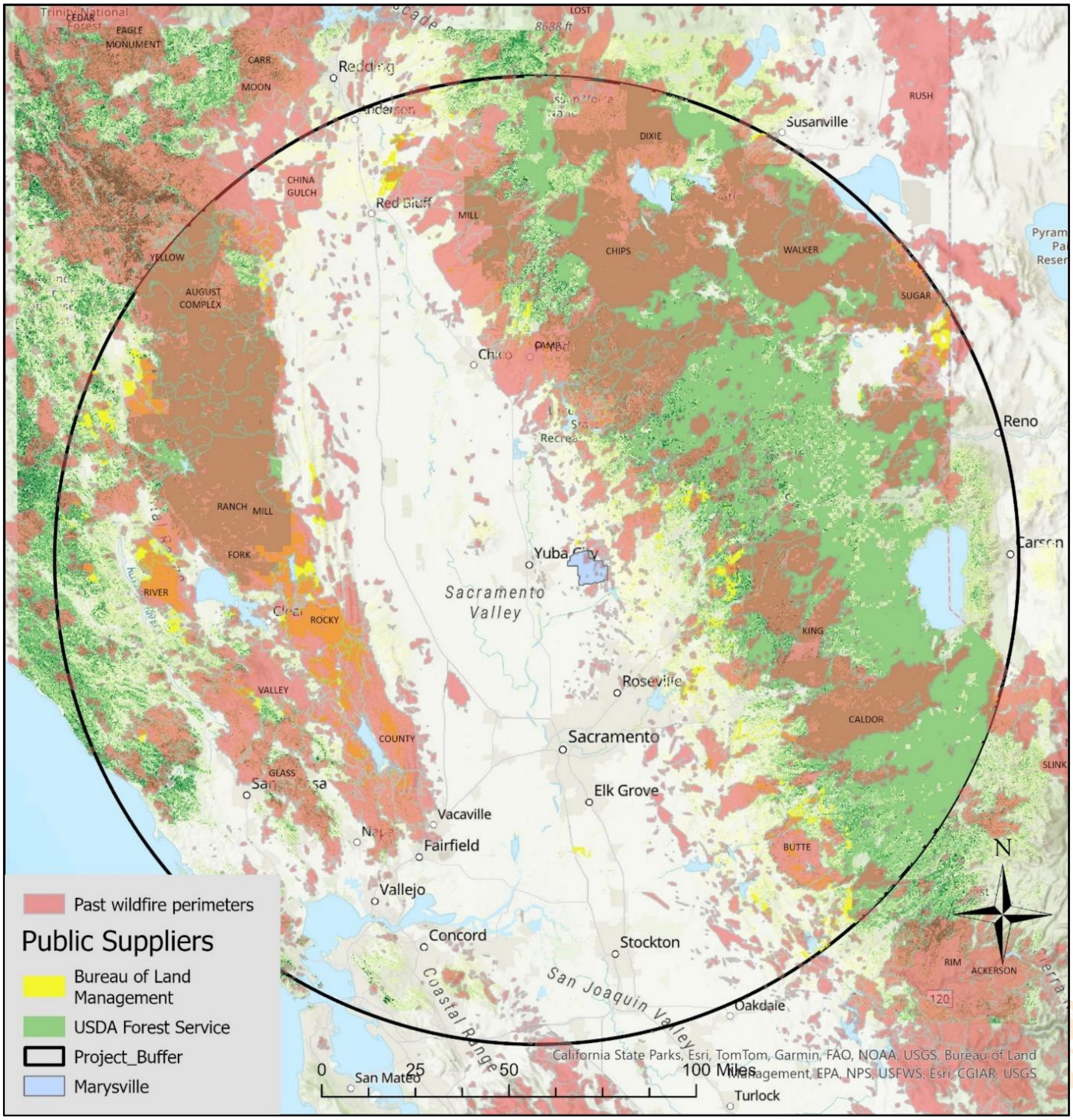

Figure 6. Public lands where the forest fuels reduction residuals will be obtained for the Marysville production facility with past wildfire perimeters.

Within the modeling effort, we limited the size to the east part of the supply radius which is in the Sierra Nevada region. We chose this side of the supply radius for treatment modeling due to the high concentration of merchantable wood in this area found through our preliminary FVS modeling. By selecting this fraction of the supply radius, the modeling was able to be more time efficient while still producing the volume target needed of 82,500 BDT. This resulted in 33,997 federal acres treated through the REM approach (Figure 7).

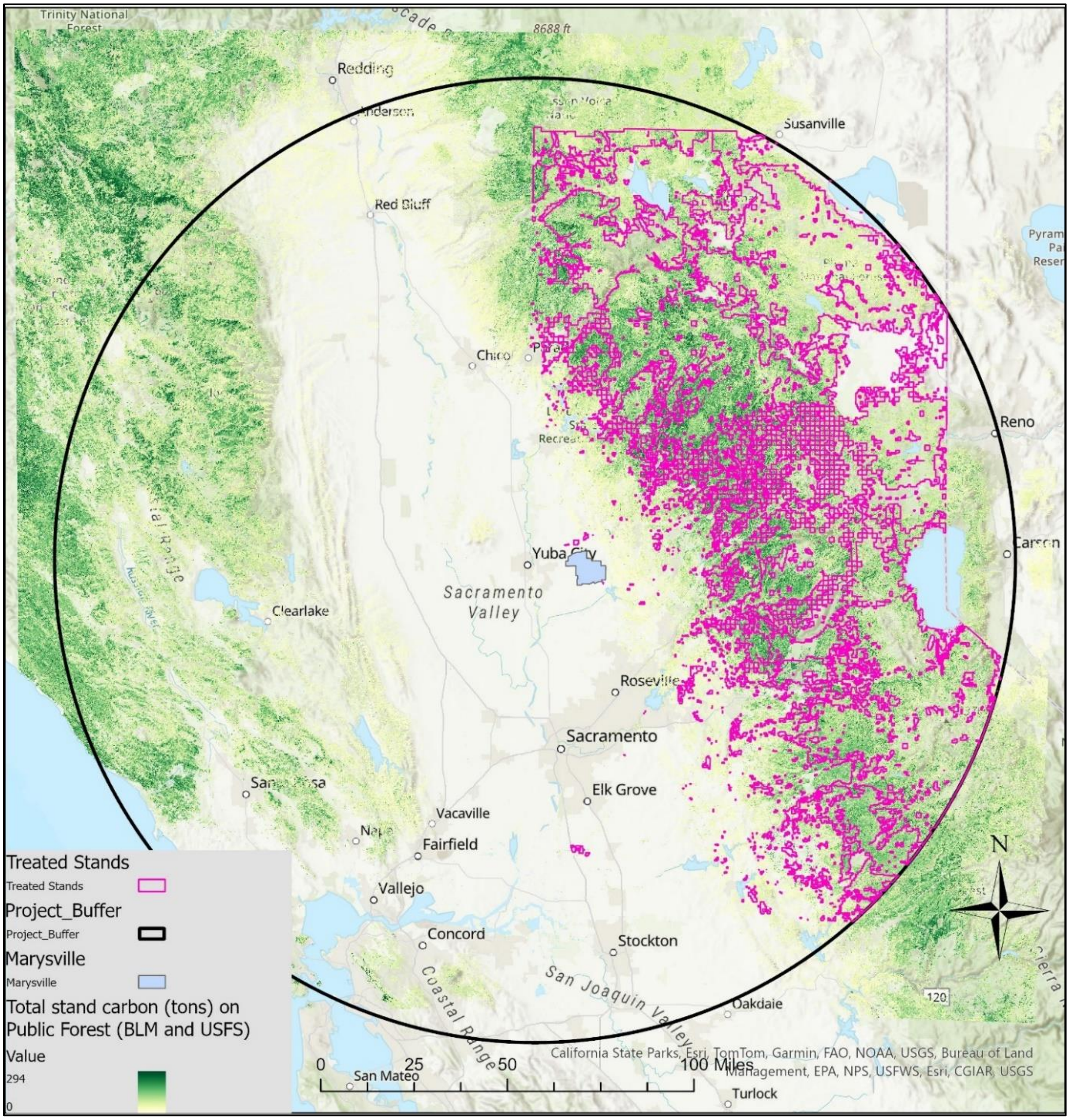

Figure 7. Stands treated in the West Forest Supply Area with total stand carbon shown.

Fuel treatment prescriptions

The thinning treatments in the supply radius of the Marysville production facility were modeled using the growth and yield simulation within the Forest Vegetation Simulator Fire and Fuels Extension (FVS-FFE). To model the fuel treatment, we created two species groups, one to represent the most common hardwood and one to represent the most common softwood species in the area. Each species group included approximately 25 species and both accounted for 99.7% of the species in the area. We concluded that simulating a mastication of softwood species, from our created species group, from 3-16” diameter at breast height (DBH) was accounted for to generally include the timber supply used in creating the MDF (described in further detail in Appendix A- FVS Treatment KCP). We also modeled the treatment to reduce the overall stand density index (SDI) to 200, as guided by North et al. (2022) which described the resilient thresholds of forests. An SDI of 200 was considered biologically appropriate for our study area. Further, we included two runs to assess the difference in emissions, one with a prescribed burn simulated in addition to the mastication treatment and one without the prescribed burn to allow for the two baseline scenarios (see Figure 5).

2.3.4 Urban Wood

Urban wood residuals would be sourced in urban and semi-urban areas from tree and yard maintenance as well as defensible space clearings (Figure 8). In the absence of the Marysville MDF plant, urban wood would be used for electricity generation and/or landscaping/alternative daily covers in landfills. The ‘West Forest GHG LCA_date.xlsx’ spreadsheet tool specifies and documents all input and conceptual assumptions in detail (tab ’Urban wood’).

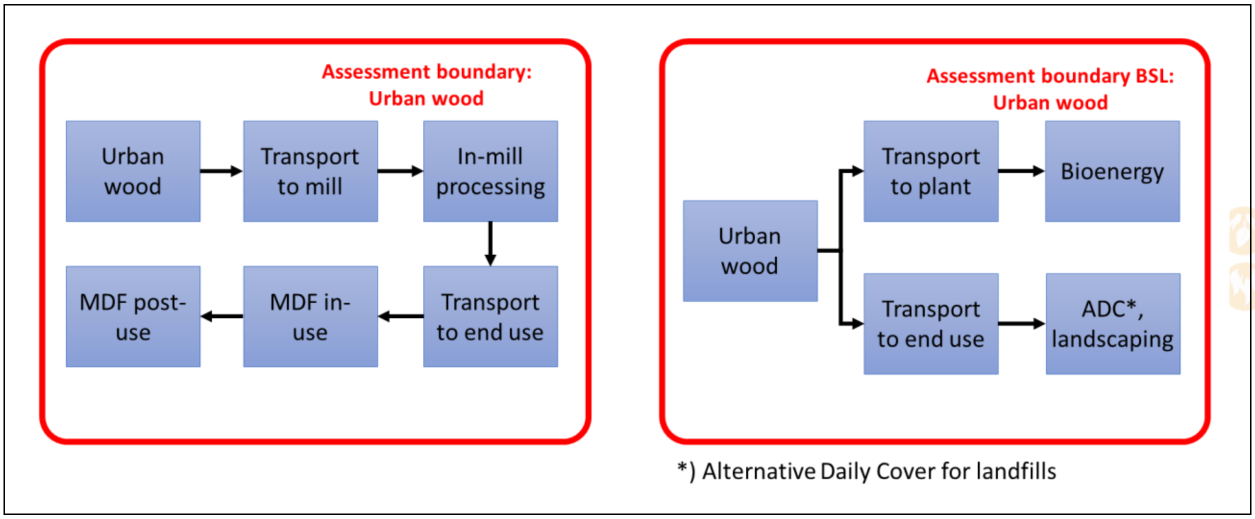

Figure 8: Analytical boundary for urban wood and associated baseline assumptions.

2.3.5 Agricultural Byproducts

Agricultural byproducts would be sourced from orchard removal operations (Figure 9). In the absence of the Marysville MDF plant, these byproducts would be pile-burnt on site. The ‘West Forest GHG LCA_date.xlsx’ spreadsheet tool specifies and documents all input and conceptual assumptions in detail (tab ‘Ag. byproducts').

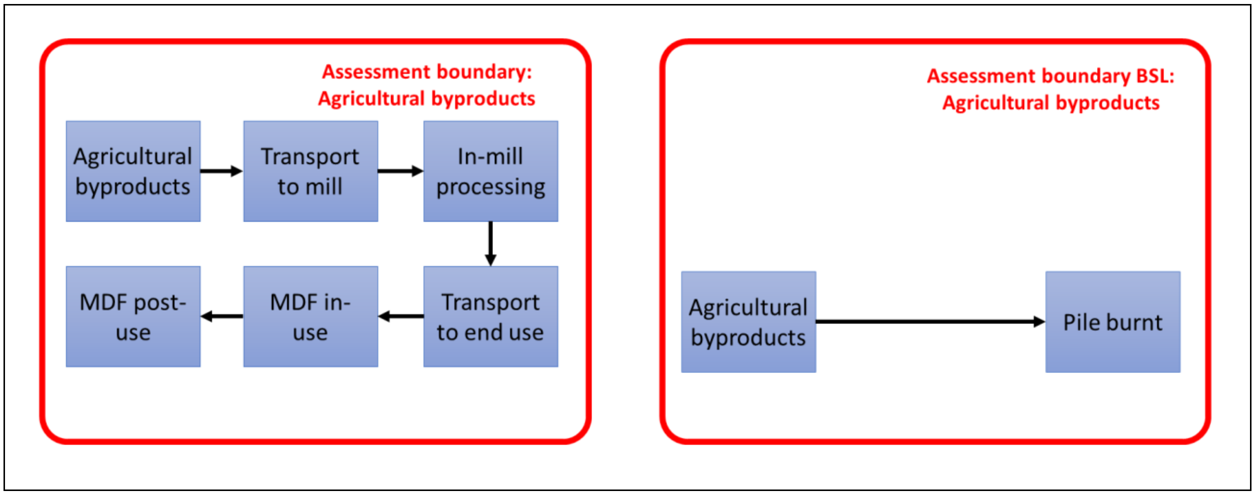

Figure 9: Analytical boundary for agricultural byproducts and associated baseline assumptions.

2.4 Consequential GHG LCA – GHG emissions from transport.

In a last step, we added a consequential GHG LCA element to the analysis that would allow for a comparison of Marysville-produced MDF vs. other domestic or international sources. The only element in this consequential GHG LCA assessment included transport emissions to the California market. The ‘West Forest GHG LCA_date.xlsx’ spreadsheet tool specifies and documents all input and conceptual assumptions in detail (tab ‘GHG trsp. Analysis’).

3 SUMMARY OF RESULTS

Overall assessment. Results suggest a net GHG emission savings for each individual feedstock source that could provide biomass to a Marysville CA based MDF production facility (Table 1). GHG emission savings varied from 0.705 (timber harvest residuals) to 3.309 (forest fuel reduction residuals) MT CO_2e per metric tonne of MDF produced. The feedstock mix presented in Table 1 resulted in a reduction of overall GHG emissions of -2.040 MT CO_2e per metric tonne of MDF produced compared to the alternative uses/non-uses of biomass. For a facility that processes 250k bone dry short tons of feedstock per year, this would equate to a reduction in GHG emissions in the range of 440k MT CO_2e per year (not considering GHG emission savings from avoided MDF imports).

GHG emission profiles by feedstock. The differences in GHG emission savings between feedstock types can largely be explained by the alternative fate of an individual feedstock. In general, potential feedstocks that create near-term GHG emissions only with no alternative use to speak of (e.g., pile burning agricultural or forest residuals) fare better when used for MDF production than feedstocks that are being already used for, e.g., electricity production (e.g., sawmill or urban residuals). Short term carbon storage (alternative daily covers) fare similar to instantaneous GHG emissions with no alternative use. Meanwhile, biomass decay (e.g., forest residuals when not affecting/affected by wildfire) can create mid-to-long term carbon storage options and therefore show reduced GHG emission benefits if used for MDF production instead.

GHG emissions from the transport sector. Overall, results were driven by baseline assumptions for individual feedstocks and less by emissions from the transport sector. For instance, with 0.132 MT CO_2e per metric tonne of MDF produced the transport sector accounted for less than 7% of overall GHG emissions for the feedstock mix presented in Table 1. Transport emissions in turn are mostly driven by mode of transport rather than transport distance. For instance, the transport GHG emissions for MDF imported to California are calculated to be in the range of 0.237 MT CO_2e per metric tonne of MDF produced; less than double of Marysville-produced MDF although transport distances are substantially higher for non-CA produced MDF. Nevertheless, an MDF production facility in Marysville would still yield GHG emission savings in the range of 23k MT CO_2e per year just by offsetting transport GHG emissions from MDF imports from non-California sources.

Table 1: GHG emission profiles per metric tonne of MDF produced. Results are presented for production and use for MDF produced in Marysville using a default feedstock mix, transport GHG emissions for MDF produced in Marysville and MDF originating from outside of California. The last section presents net GHG emissions (comparative LCA) when considering the same production/use/post-use emissions but different transport GHG emissions to show potential minimum GHG savings when producing MDF in-state.

	Feedstock (Bone dry short tons)	Feedstock (% of total)	GHG profile (MT CO2e/MT MDF)	Comment
Marysville CA MDF production, use, and post use				
Timber Harvest Residuals	30,000	12%	-0.705	BSL: Residuals left on site (50%)/pile burnt (50%)
Sawmill Residuals	40,000	16%	-1.550	BSL II – Current use of sawmill residuals replaced with agricultural byproducts
Forest Fuels Reduction Res.	82,500	33%	-3.309	BSL I – Assuming no fuel treatments in absence of Marysville MDF production and feedstock offtake; no avoided wildfire emissions
Urban Wood	37,500	15%	-1.529	BSL: 30% to bioenergy, 70% to short-term use
Agricultural Byproducts	60,000	24%	-1.610	BSL: Pile burnt on site
Total	250,000	100%	-2.040	
MDF transport				
Marysville MDF			0.132	Dist. source to mill 61mi; trsp to market 476mi (50% truck with 50% empty return; 50% train)
Non-Marysville MDF			0.237	Dist. source to mill 40mi; Domestic prod.: 50% of total w. trsp to market 1,418mi (50% truck; 50% train); Int. prod.: 50% of total w. trsp to market 575mi (50% truck; 50% train) and 5,845 Container ship - ocean
Net transport GHG savings			-0.105	
Marysville CA MDF prod. & trsp. GHG profile			**-2.145**	

REFERENCES

Crookston, N. L. (2022). *User's Guide To The Event Monitor: Part of Prognosis Model Version 6*.

ISO. (2006a). *International Standard ISO 14040—Environmental management—Life cycle assessment—Principles and framework* (ISO 14040:2006(E); p. 28). International Organization for Standardization.

ISO. (2006b). *ISO 14044—Environmental management—Life cycle assessment—Requirements and guidelines* (ISO 14044:2006(E); p. 54). International Organization for Standardization.

Lutes, D. C. (2016). *First Order Fire Effects Model Mapping Tool: FOFEM Version 6.3 user guide* (p. 81). USDA Forest Service, Rocky Mountain Research Station, Fire Modeling Institute. http://semllc.org/downloads/fofem/FOFEM6_Help.pdf

North, M. P., Tompkins, R. E., Bernal, A. A., Collins, B. M., Stephens, S. L., & York, R. A. (2022). Operational resilience in western US frequent-fire forests. *Forest Ecology and Management*, *507*, 120004. https://doi.org/10.1016/j.foreco.2021.120004

Rebain, S. A., Reinhardt, E. D., Crookston, N. L., Beukema, S. J., Kurz, W. A., Greenough, J. A., Robinson, D. C. E., & Lutes, D. C. (2022). *The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation* (p. 417). United States Department of Agriculture Forest Service.

Riley, K. L., Grenfell, Isaac C., Finney, M. A., & Shaw, J. (2019). *TreeMap 2016: A tree-level model of the forests of the conterminous United States circa 2016*. https://www.fs.usda.gov/rds/archive/Catalog/RDS-2021-0074

Van Dyck, M. G., & Smith-Mateja, E. E. (2023). *Keyword Reference Guide for the Forest Vegetation Simulator*. https://www.fs.usda.gov/fmsc/ftp/fvs/docs/gtr/keyword.pdf

APPENDIX A- FVS TREATMENT KCP

Below the keyword prescription file (KCP) that is input into FVS to outline the fuel treatment prescription that was applied to all forested stands in this project. This project uses FVS keywords and functions described in further detail in the Van Dyck & Smith-Mateja (2023) and Crookston (2022). In order to thin to a target SDI of 200 within the softwoods group and within the DBH range of 3-16”, post treatment stand SDI maybe be larger than 200 if removing all softwoods 3-16” was not sufficient to reach the target SDI. All of the lines starting with a “ * ” are essentially inactive in the modeling but provides detail.

```
*******

* this is the range we want to cut (SW, 3-16")

SDI316SW = SPMCDBH(11,GRP_SW,0,3,16,0,999,0,0)

* these are 3-16" hardwoods that are not cut

SDI316HW = SPMCDBH(11,GRP_HW,0,3,16,0,999,0,0)

* these are > 16" all species that are not cut

SDI_GT16 = SPMCDBH(11,0,0,16.1,999,0,999,0,0)

* these are < 3" all species that are not cut

SDI_LT3= SPMCDBH(11,0,0,0,2.9,0,999,0,0)

END


* only cut 3-16" softwood trees but attempt to reach all-stand SDI of 200

* ThinSDI

*        overall residual SDI=200,

*        cutting efficiency=1,

*        0-16 DBH

*        1= thin from below within the diameter range

ThinSDI      2023    Parms(MAX(0.,200-SDI316HW-SDI_GT16-SDI_LT3),&

1.,GRP_SW,3.,16.,1.)


* Prescribed fire included in one run and commented out in the other

*FMIn
```

```
* Args: 1hour, 10hour, 100hour, 3+, duff, live woody, live herb
*Moisture        2023     Parms(15., 15., 15., 15., 20., 150., 150.)
* Args: Wind, Moisture, Temp, MortCode, PAB, Season
*SimFire         2023     Parms(13, 3, 85., 1, 95, 1)
*END
```