WESTAR/WRAP PROJECT

A CONCEPTUAL MODEL FOR LONG-TERM FIRE DATA SUPPORT

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The goal of this project is to establish technical standards and identify products and services needed for long-term availability of high-quality fire emissions data to support stakeholders with regard to NAA designation, "exceptional event" identification, background level definition, and fire emissions management strategy evaluation. This has broad implications for regulatory actions pertaining to air quality, as this project's deliverables are intended to address existing critical needs for high-quality emissions data for one of the largest single source category ("wildland fire emissions") for criteria pollutants in the United States.

Core Principles

WESTAR/WRAP has drafted a set of core principles to guide the development of the Conceptual Model for Fire Data (CMFD) and to help direct engagement by members of the Core Science Team (CST) and other stakeholders. The draft core principles are:

1. Recognition that fire emissions inventories (EIs) currently used for regulatory and research applications are not typically developed with a set of data quality standards and metadata requirements as rigorous as those required for EIs developed for other significant source sectors.

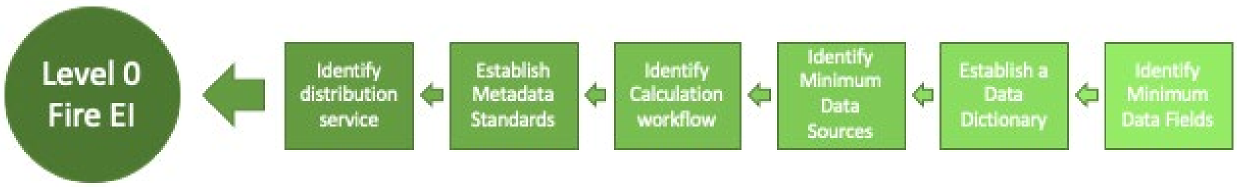
2. Recognition of a critical need for services and/or products that provide vetted, metadata-rich fire emissions datasets for a variety of modeling and analysis applications at defined levels of quality.

3. Recognition of the need for long-term support for fire emissions products or services to maintain consistency and continuity for stakeholders.

Principle 1: Fire Data Standards

Primary goals: Determine/designate the characteristics of a Level 0, 1, 2, (3?) *retrospective* fire EI; Identify the required metadata elements.

Figure 1. Example of a conceptual model of an EI product built following the core principles



Since the WRAP first embarked on building its first annual fire EI for the year 2002, there has been an obvious trend of increasing complexity of the EI products. As new sources of fire event data became available (perimeters, satellite detections, burn severity), a process of "reconciling" information from different data streams was established as data providers and EI end-users strove to maximize accurate fire event capture. Meanwhile, advances in mapping vegetation classes, characterizing fuelbeds, modeling fuel consumption, and developing emission factors (EFs) resulted in a multitude of calculation pathways that could be used to estimate emissions. These two efforts—maximizing data capture through data stream reconciliation, and more sophisticated consumption and emissions calculations—have driven EI development methods for the past decade.

An assumption underlying recent EI efforts is that maximizing fire event data capture and applying the most complex calculation pathways translates to improved EI quality. However, although many sources of uncertainty of been identified[1], limited attempts have been made to quantify the magnitude and direction of uncertainties. Table 1 presents an approach to thinking about fire EI quality from a quantitative perspective. A key concept here is isolating the *completeness* of an EI in terms of accounting for events (detected or reported) from the *uncertainty* associated with the information available for those events. Bounding the uncertainty of the emissions estimates in the EI is a critical measure of EI quality and necessitates having comprehensive metadata for each data element.

Table 2 is a representation of one of the possible outcomes from this project: *Examples* of primary data elements[2] required to build a fire emissions inventory are listed along with an assessment of the minimum level of quality for the data element. Through consultations with experts and participants' input at CST meetings and stakeholder workshops, the efforts of this project would mature this table to serve as a blueprint for EI construction.

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[1] See, most recently, Jaffe, D.A., O'Neill, S.M., Larkin, N.K., Holder, A.L., Peterson, D.L., Halofsky, J.E. and Rappold, A.G., 2020. Wildfire and prescribed burning impacts on air quality in the United States. *Journal of the Air & Waste Management Association*, *70*(6), pp.583-615.

[2] Primary data elements (e.g., fuel consumption) will rely on important secondary data elements (e.g., fuel type, fuel moisture) as inputs. Secondary data elements will also require data quality standards and metadata.

An important EI characteristic missing from Tables 1 and 2 is *scale*. The scale of an EI required for a particular air quality analysis will influence the amount and types of information needed to build an EI of a particular quality level. For example, the amount of information required to build a Level 3 EI may make it impractical to develop an EI beyond a subregional scale due to existing constraints on data availability or quality.

Table 1. *EXAMPLE*—Quantitative Approach to Determine EI Levels Based on Uncertainty of Data Element Categories

EI Level (Effort, Quality)	Event Information (Percent Capture*)	Activity Information (Percent Uncertainty*)	Consumption/ Emissions (Percent Uncertainty*)	Time Resolution	Applications/ Examples of AQ Analyses
0	85	150	200	Event Real-time	Operational/ SMP FINN
1	90	90	150	Daily	NEI WRAP RH PGM
2	95	70	90	Daily	NAA SIPs/ EER Demos
3	98	40	60	Hourly	All?

*Percent Capture and Percent Uncertainty values presented here are informed guesses. Determining realistic thresholds will be part of this project and may be a difficult effort.These values should be valid regardless of domain size or scale, but the information needed to determine the values will change.

As Table 2 is developed and refined, consideration will need to be given to the inter-dependency of certain datasets and calculation streams. For example, the decision to use the CONSUME consumption model results in a commitment to use CONSUME's data and calculation streams it relies on for inputs (e.g., FCCS). In addition, the nature and availability of datasets has changed dramatically over the last 15 years since the first WRAP annual fire emissions EI was built, and we can expect more changes in the future. As much as possible, the conceptual model should aim to "work" independent of a particular dataset or calculation stream, instead focusing on fundamental inputs and their uncertainties.

Table 2. ***EXAMPLE*** **—Minimum EI Data Elements and Detail for Increasing EI Levels.**

	Data Element	Definition	Level 0	Level 1	Level 2	Level 3
Event Information	Start Date	The start date of the burn	Date reported or detected	Date reported or detected	Date reported	Date and time reported
	End Date	The last day of significant emissions from the burn	Date reported, detected, or derived	Date reported, detected, or derived	Date reported or detected	Date reported or detected
	Location	Geographic definition for where the burn occurred	County centroid PLSS centroid Point location Burn scar polygon	County centroid PLSS centroid Point location Burn scar polygon	County centroid PLSS centroid Point location Burn scar polygon	County centroid PLSS centroid Point location Burn scar polygon
Activity Information	Acres per day	Acres burned, blackened, or treated	Acres reported Acres derived (for small burns) Fractional area (for multi-day burns)	Acres reported Acres derived (for small burns) Fractional Acres (for multi-day burns)	Acres Reported Acres Calculated (combining detection and polygon)	Acres Reported Acres Calculated (combining detection and polygon) Burn Severity
	Burn Type	Broadcast, understory, pile, etc. Could also be burn purpose (slash, restoration, land clearing, etc)	Reported Derived Assumed	Reported Derived	Reported	Reported
	Burn Class	Prescribed, Wildfire, Ag	Reported Derived	Reported Derived	Reported	Reported
	Fuel Loading	Amount of fuel available to burn, or fuel consumed	Reported Derived from grid layer	Reported Derived from grid layer	Reported Derived from grid layer	Reported Derived from grid layer Burn Severity Prior Disturbance
	Fuel Type	Forest/habitat type, crop type, etc	Reported Derived from grid layer	Reported Derived from grid layer	Reported Derived from grid layer	Reported Derived from grid layer
Consumption and Emissions	Fuel Consumed	Amount of fuel burned during the fire	Derived using simple scalars by region, fuel type, burn type, burn class, etc	Reported Derived Calculated	Reported Calculated	Reported Calculated Burn Severity Prior Disturbance
	Emission Factors	Multipliers to estimate emissions from individual pollutants based on fuel consumed	Best available based on other data elements	Best available based on other data elements	Best available based on other data elements	Best available based on other data elements

Different jurisdictions and regions have well-established methods (e.g. CA, WA, UT, AZ) that work within those geographic domains. However, our work could serve as a blueprint for those regions to update aspects of their methods that are outdated.

Principle 2: Products and/or Services that provide high-quality fire datasets

For most regulatory modeling applications, the NEI and FINN fire EIs are the only two readily available datasets. The NEI is available every three years, and recently EPA has produced interim EIs self-assessed as lower quality. FINN is essentially available on-demand and is highly automated; the source-code is freely available for independent use. However, these datasets are made available "as-is" without comprehensive metadata included.

The Fire Emissions Tracking System (FETS) was created to provide a regional hub for states and tribes to submit fire tracking and emissions data with the expectation that those data would then be incorporated into regional (or national) EIs that they could then use. With the FETS being retired (discussed further below), the only avenue S/L/Ts have to have their data included in EIs beyond their boundaries is to submit their activity data upon EPA request (every three years). In so doing, S/L/Ts lose control over how those data are processed, transformed, and/or discarded in EPA's final product. These problems with recent/existing fire emissions inventory systems illustrates the need for the annual tracking of fire activity done by many western states to be incorporated into annual EIs that are developed per data quality standards and made available on a reasonable schedule.

Upwards of 90% of fire emissions on an annual and national scale come from large, multi-day wildfires. However, regionally, prescribed fire activity can dwarf wildfire emissions, especially at certain times of the year. While exposure to smoke from prescribed fires is generally not a human health emergency, there is increasing evidence that chronic exposure to low levels of smoke can have adverse health outcomes (Reid et al.).

As indicated in the information presented in Table 2, "high-quality fire datasets" are developed from three critical data input types: events/activity, fuels, and emission factors. Information about sources of these data input types is presented below.

Fire Events and Activity

The three primary sources of fire activity data available each provide critical information, although accurately using the activity data requires care as there is some overlap and potential for double counting:

- Satellite detections provide consistent, national coverage of burning activity down to a certain heat threshold, barring cloud (or smoke) cover. These detections are critical for time-resolving activity for multi-day events and for capturing activity in areas without active smoke management.
- Accomplishment reports for small fires (such as those tracked by states and tribes) fill in major gaps left by satellite detections by providing time-resolved information about small-scale, low-temperature burns (and burns that occur during periods of obscuring clouds or smoke).
- Fire perimeter polygons provide important information for sizing large burns, since satellites have low spatial resolution.

A recent review by Jaffe, et al. (2020) reports that combining and/or reconciling multiple data sources of different types leads to much higher, and generally more complete, estimates of activity compared to relying on a single reporting agency.

Fuels and Emissions

Jaffe, et al. (2020) provides an excellent summary of the current state-of-the-science regarding EFs. While there is much active research on refining and organizing EFs for various fuelbeds across the United States, the researchers themselves do not mince words when characterizing the complicated and uncertain fields of EF and fuel consumption study: "…the uncertainties in the measurement and calculation of EFs are eclipsed by the immense variability of emissions from varying fuels and combustion conditions." (Jaffe et al, 2020, p. 595)

Experts and EI end-users consider the characterization of fuelbeds in forests and rangelands and combustion conditions (derived from fuel moisture and meteorological variables) to be the most critical pieces of the emissions calculation stream. To efficiently develop a fire EI of any appreciable scale, it is necessary to rely on gridded datasets that characterize vegetation and moisture conditions over large geographic areas derived from remote sensing data. For fuels specifically, this carries significant uncertainties both in the fuelbed (vegetation type) assignment for a given pixel and due to changes in fuel quantity and condition that occur over time. Uncertainties increase with time elapsed from the vintage of the remotely sensed data as new disturbances and continued vegetation growth alter the landscape.

A recently completed Joint Fire Sciences project, led by Michigan Tech Research Institute (MTRI) and the Univ. of Washington, tackles this problem head-on[3]. They propose a probability-based approach to using fuels for emissions calculations, and created a national-scale, gridded fuels database[4] to allow for such an approach to be implemented. It is not readily clear if/how this database will be updated or maintained over time.

In order to account for annual landscape changes, the LANDFIRE project[5] provides a number of national grids and vector files with disturbance events, vegetation, and fuel changes. Datasets are available for select metrics through 2020; annual disturbance data stopped updating after 2016.

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[3] https://www.firescience.gov/projects/15-1-01-1/project/15-1-01-1_final_report.pdf

[4] https://fuels.mtri.org/home

[5] https://www.landfire.gov/version_comparison.php

Principle 3: Establishing long-term support for fire data products

With a changing climate, dynamic forest ecosystems, and the ongoing priorities to manage the natural landscape and air quality across the U.S., the need for fire emissions data products of sufficient quality is not going to go away anytime soon. WESTAR/WRAP has identified a goal for this project to develop a sustainable model for producing and delivering an essential fire EI product of sufficient quality that contains only the essential data elements and upon which higher quality datasets can be built and made available.

Regardless of how EIs are developed and on what system they are kept, the "business" of maintaining continuity and stability of fire emissions datasets for air quality applications has yet to mature. The fate of the WRAP's FETS is an instructive case. Keeping up with the demands of evolving state and tribal smoke management programs, turn-over of invested agency personnel, and incorporating input data streams and emissions calculation methods that steadily evolved over time required near-continuous investment in the FETS to keep it updated, relevant and useful to end-users. In the end, the interest in the FETS among stakeholders and available funding sources were not strong enough to keep it alive.

One of the lessons of the FETS is that it is not enough to provide a portal for the information to live—the FETS showed that maintaining such a portal was cost-effective and stable. Equally critical is to maintain interest in and financial support for producing the products that reside at the portal. Thus, the calculus for determining what to emphasize in an essential EI product includes the indispensability of the product and the cost and timeliness with which it can be produced.