Panta Rhei
Research Program

Research Briefings · Public-Good Impact Dossiers

Disaster · **Climate, Atmosphere & Weather Systems**

τ for Wildfire, Smoke, Heat, and Compound-Extreme Health Protection

Conditional public-good pathway for Wildfire, Smoke, Heat, and Compound-Extreme Health Protection

Public-Good Impact Dossier

Conditional impact analysis · Publication-ready PDF · not deployment-ready

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Conditional scenario map. No validation, product, deployment, or policy claim.

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Release status

This briefing is a conditional public-good impact dossier released as a publication-ready PDF artifact on 2026-05-02. Publication-ready means the dossier is downloadable, internally consistent, and claim-safe. It does not validate the τ-framework, does not claim deployment readiness, and does not assert that the described domain system already exists. It maps a plausible impact pathway if the relevant upstream Results, Corpus constructions, and translation assumptions survive expert review and domain benchmarking.

What this dossier claims

- maps a conditional public-good impact pathway
- identifies upstream framework dependencies that would have to survive review
- states translation assumptions, benchmark needs, and governance guardrails

What this dossier does not claim

- does not validate the Tau framework
- does not claim that a domain system or product already exists
- does not claim deployment readiness, policy adoption, or certified impact
- does not replace independent domain review, empirical benchmarking, or governance assessment

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Contents

1 Executive Summary

This dossier examines one of the most directly human-facing applications in the entire Panta Rhei disaster portfolio: whether a physically faithful, bounded-error, coarse-grainable τ hazard twin can close the gap between fire-weather prediction, smoke-transport forecasting, heat-health warning, and the compound-extreme protection that current fragmented systems cannot reliably deliver. Under the explicit τ assumption, the answer is affirmative — and the public-good scale is substantial enough to make this a first-tier deployment priority.

The institutional baseline is already stark. The U.S. National Interagency Fire Center reports that 77,850 wildfires burned 5,131,474 acres in 2025, destroying 18,385 structures, including 12,773 residential properties. WHO/Europe states that extreme heat claimed more than 60,000 lives in 35 countries in 2022 and 47,500 in 2023, and that without adaptation this burden could reach 120,000 heat-related deaths per year in Europe alone by 2050. Australia's Black Summer of 2019–20 burned 18.6 million hectares, killed 34 people directly and an estimated 445 more through smoke, and imposed AUD 103 billion in total economic costs. The IPCC Sixth Assessment Report finds that fire weather danger increases across all high-emission scenarios.

What is still missing in most operational systems is a planning core that is physically faithful across all the coupled hazards — fire behavior, atmospheric smoke transport, heat stress, and compound exposure — rather than siloed within agency-specific tools. That coupling is precisely where τ, understood as a law-faithful fire-atmosphere-health twin, would provide differentiated value.

Seven key findings:

1. **The fragmentation problem is structural, not technological.** Fire-weather prediction, smoke transport, heat-health warning, and compound-event management currently operate as largely separate service streams across different agencies. The greatest preventable harm occurs in the gaps between those streams, during events that combine fire, smoke, and heat simultaneously.
2. **A τ law-faithful twin changes the architecture of the product.** The shift is not from a less accurate atmospheric model to a more accurate one. It is from stacked single-hazard approximations to a unified physical substrate in which fire spread, smoke lofting and transport, and heat dynamics are coupled and co-evolving, producing actionable compound-risk products that siloed systems cannot generate.
3. **The opportunity baseline is very large.** Fire suppression costs in the United States alone average USD 3.4 billion per year (NIFC). Smoke-related PM2.5 mortality is one of the most consequential public-health burdens attributable to weather. Heat deaths in Europe and the United States represent hundreds of thousands of preventable deaths over any decade-long horizon. Even small percentages of that burden are very large absolute numbers.
4. **Six distinct opportunity clusters can absorb τ outputs through existing institutional pipelines.** Operational wildfire spread intelligence, smoke-transport and exposure prediction, heat-health action and worker protection, compound heat-smoke event management, public-space and school cleaner-air operations, and ecological and occupational response planning can all be addressed without requiring new institutional architecture.
5. **The competitive landscape confirms the gap.** NASA FIRMS, ECMWF CAMS, EFFIS, CAL FIRE/FARSITE, Pano AI/DRYAD, and NOAA NBlend together represent mature institutional and commercial capacity. None provides a physically coupled, bounded-error fire-smoke-heat twin that connects fire behavior and atmospheric transport directly to health-outcome prediction and compound-risk decision support at neighborhood resolution.
6. **Climate finance architecture already exists for this domain.** The Green Climate Fund's resilience-to-climate-change windows, the World Bank GFDRR wildfire component, the EU Civil Protection Mechanism, USAID Bureau for Humanitarian Assistance, and UNDP CREW are

all eligible funding channels. National wildfire intelligence platform costs are estimated at USD 2–6 million setup with USD 0.5–1.5 million per year in operations; regional Mediterranean or Southern Hemisphere platforms at USD 15–40 million.

7. **This is a breathing, working, and living paper, not only a forecasting paper.** The highest-value consequences of better fire-smoke-heat physics are not marginally improved probability outlooks. They are avoided displacement, reduced smoke-caused premature death, protected outdoor workers, kept schools open or closed at the right moment, and cooling centers activated before heat peaks rather than after lives are lost. This is the compound-extreme health protection paper of the disaster portfolio — the paper most directly about what it costs to live in a world with accelerating fire and heat.

2 Why This Matters Now

2.1 Wildfire, smoke, and heat are converging into a single accelerating hazard system

Wildfire, smoke, and extreme heat are not three separate problems with three separate management chains. They are physically coupled components of one accelerating hazard system. WMO's heatwave guidance states explicitly that heatwaves amplify wildfire and smoke risks, and that multiple risks interact with heatwaves, including drought, fire weather, flash flooding, and air pollution. WMO's air-quality bulletin adds that there is growing scientific consensus that heatwaves increase wildfire risk and severity, and that wildfire smoke affects air quality, health, ecosystems, and crops.

The IPCC Sixth Assessment Report provides the physical framing. Fire weather — the combination of high temperatures, low humidity, low fuel moisture, and favorable wind conditions — is projected to increase in frequency and intensity in most fire-prone regions under all high-emission pathways. At 4°C of global warming, fire weather danger escalates dramatically across southern Europe, western North America, southern South America, southern Africa, and Australia. Even at 2°C, which represents the current lower-bound of plausible trajectories under current policies, fire season length and peak fire weather intensity increase substantially in nearly every inhabited fire-prone region.

This matters for the τ opportunity because it means the problem set is not stable. The operational systems that exist today, which were already struggling under 1.2°C of warming, will face substantially larger demands over the next two to three decades without fundamental improvements in the quality of fire-weather, smoke, and heat intelligence.

2.2 The Wildland-Urban Interface has brought fire to where people live and work

The wildfire problem is not confined to remote forests and unpopulated rangeland. The U.S. Forest Service estimates that more than 32 million homes in the United States are located in the Wildland-Urban Interface (WUI) — the zone where built residential and commercial structures intermingle with or are adjacent to wildland vegetation. This is where most structure losses occur. It is where fire behavior prediction matters most directly for life-safety decisions, evacuation timing, crew staging, and insurance outcomes.

The WUI problem also transforms the nature of what fire-weather intelligence needs to do. A forecast that is useful for fire crew operational safety in a remote forest is different from a forecast that determines whether 40,000 people need to evacuate a suburban corridor in the next six hours. The former can tolerate moderate spatial uncertainty; the latter cannot. The former primarily benefits fire crews; the latter protects entire communities. τ's potential to provide finer, more locally faithful fire-behavior forecasts is most consequential precisely where fire meets people.

2.3 Smoke is no longer a regional nuisance; it has become a continental public-health burden

The smoke dimension of the wildfire problem has changed qualitatively over the past decade. The 2020 California fire season produced a smoke plume that reached Europe, documented by NOAA. The 2023 Canadian wildfire season deposited smoke across the eastern United States and as far south as the Caribbean, generating air quality index readings in New York City that exceeded levels recorded in Beijing. EPA states that wildfire smoke can travel hundreds to thousands of miles and is associated with respiratory and cardiovascular exacerbation and premature death in populations far from any active fire.

The public-health burden of smoke is now one of the most significant mortality-attributable weather-adjacent exposures in North America, Europe, and Australia. Research published in the Lancet and other peer-reviewed outlets documents tens of thousands of smoke-attributable excess deaths per year in global aggregations, with disproportionate impacts on children, the elderly, and those with pre-existing cardiovascular and respiratory conditions.

For τ, this means the smoke opportunity is not only about better smoke forecasts for fire crews. It is about a public-health intelligence layer that can protect urban populations who are far from any flame but who face sustained, damaging exposure.

2.4 Heat governance is emerging but its physical intelligence base remains weak

In 2025, WMO launched an Extreme Heat Risk Governance Framework and Toolkit designed to help decision-makers strengthen governance across sectors and scales. WHO and WMO issued joint guidance identifying heat stress as a global worker-health crisis: productivity falls 2–3 percent for every degree above 20°C, and approximately half the global population experiences adverse consequences of high temperatures. WHO/Europe identified heat as responsible for more than 60,000 deaths in 35 European countries in 2022 alone.

The governance architecture is emerging. Heat-health action plans now exist in dozens of countries. Cooling-center networks are expanding. Occupational heat regulations are being strengthened. But the physical intelligence base that feeds all of these plans — the local heat-risk forecast that tells a city when to open cooling centers, tells an agricultural employer when to stop outdoor work, tells a school when to cancel outdoor activities — remains patchy, coarse, and often disconnected from the smoke and fire dynamics that compound heat risk. This is the gap τ would fill.

2.5 Compound events are where lives are most at risk

The deepest insight in this paper is simple: compound events — heat plus smoke, drought plus fire weather, poor overnight recovery plus high PM2.5 concentration — are where the largest harm concentrates. A heat episode in which smoke prevents indoor cooling (because opening windows would worsen air quality) while the power grid is stressed and outdoor workers have no effective rest-shade-hydration protocol is a qualitatively different emergency than any single component managed in isolation.

Existing systems are architecturally incapable of managing compound events well because they are built around single-hazard service chains. The fire agency issues fire-weather and spread advisories. The air-quality authority issues smoke and PM2.5 advisories. The weather service issues heat advisories. The labor ministry has occupational heat standards. The school system has air-quality protocols. Each component may function well individually; the compound event is where they all fail simultaneously.

Under the strongest τ assumption, the contribution here is structural: replacing stacked single-hazard approximations with a unified physical substrate in which compound events can be reasoned about as one interacting system rather than as simultaneous separate alerts.

3 Scope and Reader Orientation

This document is **Paper 3 of 5** in the Panta Rhei Disaster Impact Portfolio. It focuses on the fire-smoke-heat-health protection layer of disaster resilience: the interface between fire-weather prediction, smoke transport, heat-health action, and compound-extreme response.

In scope for Paper 3:

- Operational wildfire spread and fire-behavior intelligence for emergency response agencies;
- Smoke-transport, smoke-exposure, and air-quality decision support at local, urban, and regional scales;
- Heat-health warning, cooling-center and cleaner-air-space activation, and heat-governance support;
- Compound heat-smoke-fire-weather event management, including sequencing and trigger logic;
- Worker-protection, school, childcare, and public-health response applications;
- Geographic case studies from Australia, California, and the Mediterranean;
- Competitive and incumbent tool landscape;
- Finance, ROI scenarios, and climate-finance eligibility;
- Stakeholder map and deployment ladder;
- Gender, equity, and labor dimensions;
- Governance guardrails and SDG alignment.

Out of scope for Paper 3 (covered elsewhere in the portfolio):

- Paper 1: multi-hazard early warning and operational hazard intelligence (general);
- Paper 2: flood, coastal surge, flash flood, and landslide resilience;
- Paper 4: critical infrastructure continuity and emergency operations;
- Paper 5: anticipatory action, humanitarian logistics, and climate-risk finance.

Primary audiences: National fire and civil-protection agencies; national meteorological services; public-health ministries and WHO regional offices; air-quality regulatory authorities; occupational safety and labor ministries; school systems and education ministries; city governments in fire-prone regions; emergency managers and UNDRR partners; climate-resilience funders including GCF program officers; humanitarian coordination bodies; and public-interest research laboratories working on fire-weather and health modeling.

4 The Opportunity Baseline

4.1 The wildfire operational burden is already very large and growing

The U.S. National Interagency Fire Center's 2025 annual report documents 77,850 wildfires burning 5,131,474 acres and destroying 18,385 structures, including 12,773 residential properties, in a single year. The NIFC reports an average annual fire suppression expenditure of approximately USD 3.4 billion for the United States alone. This does not include state suppression costs, property losses, business interruption, health costs, or the long-run ecological and watershed damages that amplify downstream hazards including flooding and landslides.

California's 2020 fire season, the record-setting season at that time, burned 4.2 million acres, caused USD 12.1 billion in insured losses (Swiss Re/CALFIRE), destroyed more than 22,000 structures, and killed 31 people. The smoke plume was tracked reaching Europe by NOAA atmospheric monitoring. The Camp Fire of November 2018 — not the 2020 season — remains the single deadliest and most destructive California fire on record: 85 fatalities, USD 16.5 billion in losses in Butte County alone, and the near-total destruction of the town of Paradise in approximately 90 minutes. Critically, while warnings were issued approximately six hours in advance, behavioral fire spread moved three times faster than model projections suggested, directly contributing to fatalities.

This spread-prediction failure is not an isolated accident. It is a systemic gap: fire-behavior models operating at coarse resolution and with approximated coupling between local wind fields, terrain, and fuel moisture consistently underestimate the most dangerous spread events — which are precisely the events where accurate prediction matters most.

4.2 Smoke has become a distributed continental health hazard

EPA documents that wildfire smoke can travel hundreds to thousands of miles, contributing to poor air quality in communities both near and far from a wildfire. NIOSH guidance identifies smoke as a mixture of gases, vapors, and fine particles that can cause coughing, wheezing, difficulty breathing, and exacerbation of respiratory and cardiovascular disease. The public-health literature now documents smoke-attributable excess mortality in the hundreds of thousands globally when aggregated across large fire years.

The Australian Black Summer of 2019–20 is the most comprehensively documented compound event in the recent record. Smoke from the fires caused air quality to exceed “hazardous” thresholds in Sydney for 81 consecutive days. The Medical Journal of Australia estimated approximately 445 smoke-attributable deaths, in addition to 34 direct fire fatalities, across New South Wales, Victoria, and other affected states. Hospital presentations for respiratory and cardiovascular conditions rose sharply across the eastern seaboard, including in cities hundreds of kilometers from the active fire front.

This distributed health burden is operationally significant. The demand for smoke intelligence is not concentrated at the fire perimeter — it is continental in scope and affects dense urban populations who may never see a flame.

4.3 Heat is one of the largest weather-related mortality burdens

WHO/Europe reports that extreme heat caused more than 60,000 deaths in 35 European countries in 2022 and 47,500 deaths in 2023. The agency projects this could reach 120,000 heat-related deaths per year in the European Region by 2050 without further adaptation. In the United States, CDC documents more than 700 excess heat deaths per year as a reported baseline — a figure that expert analyses consistently regard as substantially understated because of misclassification in death records.

WMO characterizes heatwaves as one of the most dangerous natural weather hazards globally. The 2022 European heat event, which drove the 60,000-death toll, exceeded 40°C at multiple stations in the UK, France, Spain, and Portugal during a period when nighttime temperatures remained dangerously high and air-conditioning coverage in residential buildings remained low. Nighttime recovery failure — the inability of the human body to recover from daytime heat stress because overnight temperatures remain elevated — is one of the most dangerous heat-episode characteristics, and one that current operational systems forecast poorly at the neighborhood level.

4.4 Compound events are the dominant risk architecture

The most harmful events in the recent record are compound events, not single-hazard episodes. Australia’s Black Summer was simultaneously a fire event, a smoke event, a heat event, and a drought event. The 2022 European heat event drove wildfire ignitions across the Iberian Peninsula, southern France, Greece, and Turkey, with smoke interacting with the heat to produce combined

PM2.5-plus-heat exposure profiles that neither health system was equipped to manage in integrated fashion.

WMO's 2025 extreme-heat reporting explicitly states that extreme heat fueled wildfires, casualties, and smoke degradation in multiple countries simultaneously. The operational significance is that the worst outcomes in these events are not explained by any single hazard component but by the failure of siloed response systems to communicate and act coherently when all components peak simultaneously.

4.5 Official systems are already moving toward integrated fire-smoke-heat intelligence — and revealing the gaps

NASA's Wildfire Digital Twin effort explicitly targets real-time burn-path and smoke forecasting at 10–30 meter regional ensemble resolution, generated in minutes rather than hours, by merging in situ, airborne, and spaceborne sensor data. NOAA's RRFS-Smoke Dust capability, expected to transition to initial operations in 2026, will provide near-surface and vertically integrated smoke forecasts over North America. NOAA's Wildland Fire Data Portal and Next Generation Fire System provide minute-by-minute satellite fire intelligence and are being expanded to full operational status in 2026.

These developments confirm that the operational weather and fire enterprise recognizes the need exactly as framed in this paper. They also reveal the gap: even the most advanced current systems treat fire spread, smoke transport, and heat dynamics as coupled at the model integration layer, but not at the level of physical substrate. The result is that high-resolution fire-spread models still use parameterized atmospheric coupling that cannot capture the fine-scale wind-terrain-fire behavior interactions that drive the most dangerous spread events.

5 Working τ Assumptions

This paper adopts a deliberate assumption-led stance. All conclusions and scenarios are conditional on the following τ assumptions being valid. They are stated explicitly so that readers can assess each downstream claim independently.

5.1 Fire-weather and spread assumptions

τ is assumed to provide a bounded-error, constructive, coarse-grainable representation of fire-weather evolution and spread-relevant atmospheric drivers. Specifically: more faithful local coupling among wind, humidity, temperature, terrain, fuels, and fire behavior than current operational parameterizations provide. Better local forecast envelopes for spread direction, rate-of-spread, spot-fire probability, and active-burn behavior at neighborhood and parcel resolution. Error bounds that are honest, calibrated, and stable under refinement, rather than showing error growth as resolution increases — which is the characteristic failure mode of current operationally-tuned numerical weather prediction when pushed to fire-relevant scales.

5.2 Smoke and air-quality assumptions

τ is assumed to provide more faithful treatment of smoke generation, lofting, injection height, transport, dispersion, and surface-exposure patterns. Better alignment between model resolution and physical fidelity, so that higher-resolution smoke forecasts are not destabilized by sub-grid parameterization choices. More decision-grade PM2.5 and smoke-plume forecasts at neighborhood, corridor, and regional scales — including accurate prediction of plume arrival timing at downwind urban centers, plume depth and exposure duration, and inter-day variability that determines whether populations can safely open windows overnight.

5.3 Heat-health assumptions

τ is assumed to provide a physically stronger local heat-risk twin that couples mesoscale meteorology, nighttime cooling dynamics, humidity, local urban heat island effects, terrain, and exposure conditions. Better local heat-risk envelopes for neighborhoods, workplaces, schools, event sites, and vulnerable-population concentrations. Honest uncertainty quantification that allows heat-health action planners to calibrate trigger thresholds with appropriate confidence rather than either over-warning or under-warning. Specifically better performance on nighttime recovery failure prediction — the single most dangerous heat-episode characteristic.

5.4 Compound-event assumptions

τ is assumed to provide a stronger joint treatment of heat, drought, fire weather, smoke, and health exposure as a physically coupled system. Better event sequencing and trigger logic for compound conditions, including the ability to forecast when a combination of heat, poor overnight recovery, active fire weather, and elevated PM2.5 concentrations will peak simultaneously — the conditions that drove the worst health outcomes in Australia, California, and Europe. Rather than siloed alert streams from separate agency systems, τ would provide a compound-risk product that integrates all hazard components into a single structured decision surface.

5.5 What this paper does not assume

This paper does not assume that all wildfires become predictable, that all smoke exposure can be prevented, that all local vulnerability data already exist and are equitably distributed, or that forecasting alone eliminates risk without complementary investments in labor standards, building codes, cleaner-air spaces, and public-health capacity. The claim is narrower and more practical: if the hazard twin is physically more faithful and coherent across coupled hazards, then a large class of avoidable exposure, mistimed warnings, overbroad closures, under-protection, and false confidence becomes tractable.

6 What Changes with a Law-Faithful Twin

6.1 The architecture shifts from stacked approximations to a unified physical substrate

Today's operational architecture is fragmented by design. Fire-behavior modeling systems (FARSITE, FlamMap) take wind fields from atmospheric models as boundary conditions and propagate fire forward through fuel-moisture and terrain-slope parameterizations. Smoke systems (HRRR-Smoke, CAMS) take fire emission estimates as inputs and transport them through separate atmospheric transport models. Heat-warning systems (HeatRisk, national meteorological thresholds) use temperature and humidity forecasts from yet another model chain. Each step in this cascade introduces approximation, misalignment, and temporal lag.

Under the strongest τ assumption, this architecture changes. Fire spread is not extrapolated from coarsely coupled wind and moisture fields but driven by a more faithful physical substrate that resolves the local atmospheric dynamics that matter most for fire behavior — particularly the interactions between terrain-induced flows, fire-induced convection, and ambient wind that drive the most dangerous rapid-spread events. Smoke forecasts are not post-hoc transport calculations from emission inventories but co-evolving fields in the same physical substrate. Heat risk is not a threshold product applied to a temperature field but a local, dynamic, exposure-aware hazard layer that knows the fire situation and the smoke concentration simultaneously.

The operational consequence is significant: the decision product available to emergency managers, air-quality officers, health departments, and school administrators changes from "fire is dangerous somewhere, smoke may be bad tomorrow, heat is elevated" to something like: "this fire corridor is likely to intensify under these winds from hour 4 to hour 12, this downwind air basin will enter unhealthy PM2.5 bands by 0400, overnight heat will prevent recovery for this neighborhood, these workers and schools are highest risk, these cleaner-air and cooling actions should happen now."

6.2 Advance warning times increase for the events that matter most

The failure mode of current operational systems is not generally in calm conditions or moderate events — it is in the rapid-escalation events that produce most of the harm. Paradise was destroyed in 90 minutes. Australia's worst fire days occurred when forecast models had underestimated wind shift intensity and fire-atmosphere coupling. The 2022 European heat event reached record temperatures in regions where historical analogs were absent and numerical weather models were poorly calibrated.

Under the τ assumption, the physical fidelity of the model means that rapid-escalation events — the conditions where fire behavior, smoke injection, and heat stress all worsen simultaneously — are predicted more faithfully. The operational translation is additional advance warning time precisely when it is most needed. An advance warning gap of three to seven days for compound fire-weather episodes, as identified in the Australian Black Summer post-event review, becomes addressable not by better data collection but by better physics.

6.3 The public-health intelligence layer becomes health-outcome aware rather than hazard-threshold aware

Current smoke and heat warnings are threshold products: AQI exceeds 150, issue unhealthy alert; temperature exceeds 40°C, issue extreme heat advisory. This binary logic is operationally manageable but clinically coarse. It does not tell a cardiologist when to expect the surge in myocardial infarction presentations. It does not tell a school nurse whether the smoke today is worse for children with asthma than the smoke last week, even if the AQI number is similar. It does not tell a labor inspector which combination of heat and PM2.5 exposure constitutes the greatest occupational risk for a specific worker demographic.

Under τ assumptions, a physically faithful compound-risk product that resolves local exposure dynamics would support a transition from threshold-based to exposure-profile-based health intelligence. This is not a marginal improvement — it is the difference between telling public-health systems that conditions are bad and telling them how bad, for whom, for how long, in which neighborhoods, and how that exposure profile compares to the clinical evidence base for harm.

6.4 WUI protection becomes more credible and more actionable

The 32-million-home WUI exposure problem in the United States cannot be solved by evacuation alone. The operational reality is that most WUI fire events develop faster than evacuation systems can respond, and that the most dangerous events — like the Camp Fire — produce conditions in which evacuation routes themselves become endangered. The operational need is better advance characterization of which fire scenarios will escalate to WUI threat levels, at what speed, and in which direction.

Under τ assumptions, the combination of higher-resolution fire-behavior prediction and more faithful local atmospheric coupling provides the input needed for much more precise WUI threat assessment: which parcels are in the likely 6-hour threat envelope, which evacuation routes will remain viable, which resources should pre-stage now rather than respond after ignition. This is the difference between reactive evacuation and protective pre-positioning.

7 Competitive and Incumbent Landscape

Understanding where τ fits requires honest assessment of what existing systems do well and where they structurally fall short. The following survey covers the six most relevant incumbent tools and programs.

7.1 NASA FIRMS / VIIRS / MODIS (Fire Information for Resource Management System)

What it does well: NASA FIRMS provides near-real-time fire detection globally using VIIRS (375m resolution) and MODIS (1km resolution) satellite sensors, updated every few hours. FIRMS is free, globally accessible, and operationally trusted by fire agencies worldwide. It is the primary source of active-fire location data for most international fire-response coordination. Its historical archive spans decades, enabling trend analysis and post-event forensics.

Where it falls short: FIRMS is a detection system, not a prediction system. It tells you where fire currently is, not where it will be. The spatial resolution of 375m–1km is sufficient for detection but inadequate for the parcel-level fire-behavior prediction needed for WUI evacuation timing and structure-protection staging. FIRMS provides no smoke-transport prediction, no heat-health coupling, and no compound-risk products. Its update latency (typically 3–12 hours depending on satellite overpass timing) means it cannot support real-time incident management for fast-moving fire events.

τ differentiation: τ would use FIRMS fire-detection data as a physical anchor but would provide what FIRMS cannot: forward prediction of fire spread, smoke lofting and transport, and compound heat-smoke exposure fields at much finer resolution and with advance lead time.

7.2 ECMWF CAMS (Copernicus Atmosphere Monitoring Service)

What it does well: CAMS provides global 5-day smoke and aerosol forecasts, including wildfire-smoke PM2.5 and organic carbon fields, at approximately 40km resolution. CAMS is operationally mature, runs twice daily, is freely available, and serves as the primary smoke-forecast input for most European national air-quality agencies and for many international humanitarian response systems. Its ensemble products provide uncertainty information. It has a strong track record in capturing large-scale smoke transport across continental distances.

Where it falls short: CAMS operates at 40km resolution — far too coarse for neighborhood-level smoke exposure prediction in WUI communities, urban corridors, or complex terrain. The 5-day forecast skill for smoke concentration degrades sharply after day 2, particularly for fires that have not yet ignited or are still in early development. CAMS takes fire emission inputs from a separate fire-behavior component (GFAS) that itself has large uncertainty for rapidly evolving fires. CAMS provides no fire-behavior prediction, no heat-health coupling, and no compound-risk products integrated with fire-spread intelligence.

τ differentiation: τ would provide the fine-scale, locally faithful smoke-exposure product that CAMS is architecturally incapable of delivering, particularly for urban and WUI populations near active fires and for the rapid-escalation events where CAMS skill degrades fastest.

7.3 EFFIS (European Forest Fire Information System)

What it does well: EFFIS is the European Commission's authoritative system for fire monitoring, historical fire-damage mapping, and seasonal fire-danger forecasting across EU and neighboring countries. It provides the Fire Weather Index (FWI) system for seasonal fire-danger assessment, post-fire damage mapping using satellite data, historical fire-database analysis spanning decades, and standardized reporting to EU institutions and civil-protection authorities. EFFIS is the primary institutional reference for EU fire-risk governance.

Where it falls short: EFFIS excels at historical analysis and seasonal fire-danger communication but provides limited operational fire-behavior prediction. Its fire-danger products are coarse — adequate for seasonal planning and public communication but insufficient for day-of and hour-ahead operational fire-response decisions. EFFIS does not provide fire-spread prediction at incident scale, does not integrate smoke-transport or health-exposure forecasting, and does not address compound heat-fire events in an operationally integrated way. Its greatest strength — institutional integration and historical consistency — is also a constraint on rapid capability evolution.

τ differentiation: τ would complement EFFIS rather than replace it, providing the fine-scale operational fire-behavior and compound-risk layer that EFFIS is not designed to produce, building on EFFIS's strong institutional relationships and historical baseline.

7.4 CAL FIRE / FARSITE (Fire Area Simulator)

What it does well: FARSITE is the U.S. Forest Service's standard physics-based fire-behavior simulation tool, used by CAL FIRE and other U.S. fire agencies for incident planning and evacuation decision support. It incorporates fuel maps, terrain models, and atmospheric inputs to project fire spread, rate-of-spread, and fireline intensity. FARSITE is institutionally trusted, deeply integrated into U.S. fire agency workflows, and represents several decades of fire-behavior modeling refinement.

Where it falls short: FARSITE is expert-intensive — it requires trained fire-behavior analysts to set up simulations, interpret outputs, and update models as conditions change. This means it operates at incident-planning cadence (hours to days) rather than real-time response cadence (minutes). Its atmospheric coupling uses pre-computed wind fields from weather models rather than dynamically coupled fire-atmosphere interaction, which means it systematically underestimates the fire-atmosphere feedbacks that drive the most dangerous rapid-spread events. FARSITE provides no smoke-transport or health-exposure products, no automated WUI threat scoring, and no compound heat-smoke-fire products.

τ differentiation: τ would provide what FARSITE is architecturally unable to deliver: dynamically coupled fire-atmosphere behavior prediction that captures the rapid-escalation physics FARSITE misses, at operational update rates rather than analyst-driven cadence, with integrated downstream smoke and health products.

7.5 Pano AI, Xact Robotics, and DRYAD (Commercial IoT and AI Fire Detection)

What they do well: This category of commercial operators deploys networks of cameras, sensors, and AI image-classification systems for early fire detection. Pano AI installs panoramic cameras on towers and ridge tops, using computer vision to detect smoke and flame with detection times of minutes to tens of minutes from ignition. DRYAD deploys mesh networks of gas and environmental sensors in forest environments. These systems genuinely advance early-detection capability and have demonstrated operational value in California and other fire-prone regions.

Where they fall short: Commercial detection platforms are detection-oriented, not behavior-prediction-oriented. They tell operators that a fire has been detected; they do not tell operators how fast it will spread, where it will go, when it will reach the WUI, how much smoke it will produce, where the smoke will travel, or what the compound health risk will be for specific populations. These systems are also constrained by sensor deployment density — they work best where sensors exist and have gaps in coverage that are precisely the remote or complex-terrain areas where dangerous fires often initiate.

τ differentiation: τ would use early-detection outputs from these systems as physical anchors for initiation of fire-behavior prediction, providing the forward-looking operational intelligence that detection systems alone cannot generate.

7.6 NOAA National Blend of Models (NBlend)

What it does well: NOAA's National Blend of Models provides statistically post-processed, bias-corrected weather guidance by combining multiple NWP model outputs into a single consensus product. NBlend is operationally used for official weather forecasts across the United States and provides better skill than any single model for standard meteorological variables including temperature, wind speed, and relative humidity — all of which are inputs to fire-weather assessment.

Where it falls short: NBlend is a weather system. It provides no fire-behavior prediction, no smoke transport, no health-exposure coupling, and no compound-event products. The statistical post-processing that improves its skill for general weather variables does not extend to the fire-relevant mesoscale dynamics that determine spread behavior. NBlend represents the weather input layer; everything above that — fire behavior, smoke transport, heat-health action — must come from separate systems that are architecturally disconnected from NBlend and from each other.

τ differentiation: τ would provide the physically coherent layer above the meteorological input that connects weather dynamics directly to fire behavior, smoke transport, and health exposure in a unified physical substrate rather than a downstream stitching of separate system outputs.

8 Structured Opportunity Map

The main opportunity areas cluster into six domains that can absorb τ outputs through existing institutional pipelines without requiring new agency architecture.

8.1 Operational wildfire spread intelligence

This is the nearest-term fire-management opportunity and the one with the clearest direct connection to life-safety outcomes. A stronger τ twin could improve burn-path forecasts, rate-of-spread estimates, local wind-terrain-fireline interaction prediction, incident staging and crew-protection decisions, evacuation timing and zone design, and structure-protection prioritization in WUI environments.

The institutional demand is already documented. NASA's Wildfire Digital Twin effort explicitly targets 10–30 meter resolution ensemble fire-behavior forecasting because current operational models operate at 10km resolution — more than three orders of magnitude coarser. The NIFC's operational needs assessments consistently identify better spread prediction for rapidly evolving incidents as a priority capability gap. The Camp Fire and Black Summer advance-warning gaps are both expressions of the same structural limitation.

The public-good framing is direct: better fire-spread prediction means more credible evacuation orders issued at the right time and in the right zones, fewer unnecessary evacuations that erode public trust, better crew staging that protects firefighter lives, and more effective structure protection that preserves property and community continuity.

8.2 Smoke-transport and exposure intelligence

This is one of the largest absolute public-health opportunities in the portfolio. A stronger smoke twin could support local PM2.5 forecasts with better timing and spatial fidelity, cleaner-air-space activation in schools and public buildings, school and childcare exposure decisions, outdoor-event planning and cancellation, workplace exposure reduction scheduling, and citywide respiratory-surge planning by hospital systems and emergency medical services.

Because smoke travels hundreds to thousands of miles, this opportunity is simultaneously local and transboundary. The 2023 Canadian fires affecting the U.S. Northeast, the Black Summer smoke affecting Sydney for 81 days, and the 2022 European fires delivering PM2.5 to populations across the continent all illustrate that smoke intelligence must operate at multiple scales simultaneously — from the neighborhood where air quality will be worst, to the regional basin where the plume will arrive by morning, to the continental picture that informs international humanitarian response.

The equity dimension is significant: low-income urban populations, who are more likely to live in older buildings with poor air filtration and less likely to have home air purifiers, are disproportionately exposed to smoke harms even when fire is distant. Better local smoke forecasting that enables targeted protection of these populations is a high-value equity intervention.

8.3 Heat-health action and worker protection

This is where meteorology most directly meets public health. A stronger τ heat twin could improve local heat-risk categorization at neighborhood resolution, cooling-center activation timing and outreach logistics, worker scheduling and rest-hydration-shade trigger quality, public messaging for vulnerable groups, urban heat hotspot management, and hospital and EMS readiness planning.

The operational gap is in local specificity. National or regional heat warnings that tell a city it will be hot do not tell a cooling-center network which neighborhoods will face highest overnight heat stress, do not tell an agricultural labor operator when the morning temperature will reach thresholds requiring mandatory rest breaks, and do not tell a hospital how many heat-related ED presentations to expect and from which neighborhoods. τ's potential to provide this local, dynamic, exposure-aware heat-risk layer is the central value proposition in the heat-health domain.

The WMO/WHO worker-heat guidance provides the institutional framing: with heat stress affecting billions of workers globally and productivity falling 2–3 percent per degree above 20°C, the economic and health consequences of inadequate heat management are not marginal. Better occupational heat intelligence, tied to enforceable labor protection, is one of the most cost-effective worker-safety investments available in fire-prone and heat-prone regions.

8.4 Compound heat-smoke event management

This is perhaps the most distinctive τ opportunity in the cluster, and the one with the least incumbent coverage. Compound events are where lives are at greatest risk, because high heat, poor overnight cooling, smoke exposure, and strenuous work or inadequate housing combine to create multi-pathway health hazard that no siloed system can manage.

A stronger compound-event product could improve: combined risk triggers for multi-agency response activation; worker and school closure logic that responds to the combined heat-plus-smoke exposure profile rather than separate AQI and temperature thresholds; sheltering versus evacuation decisions in which smoke makes outdoor movement dangerous while heat makes indoor sheltering without cooling dangerous; clean-air and cooling co-location planning that identifies spaces providing both; and more realistic prioritization of health surge capacity for conditions where respiratory and cardiovascular presentations will peak simultaneously.

This is the capability gap that current systems are architecturally least able to close. No single agency owns the compound event. τ's contribution would be to make the compound event legible as a single physical system and to produce compound-risk products that existing agencies can jointly act on.

8.5 Public-space, school, and cleaner-air-space operations

This is a highly practical public-good domain. A stronger smoke and heat twin could support school recess and outdoor-activity cancellation logic that is responsive to actual local exposure rather than regional averages; wildfire-smoke indoor-air protection protocols triggered by accurate local plume arrival forecasts; cooling-center siting and opening-hours decisions tied to actual local overnight heat stress; ventilation and filtration guidance calibrated to actual smoke-plume characteristics; and targeted messaging for community organizations, faith-based institutions, and neighborhood networks serving vulnerable populations.

Schools and public spaces are equity-critical intervention points. Children in lower-income schools are less likely to have filtered HVAC systems and more likely to have large outdoor recreation requirements. Better local smoke and heat intelligence that enables targeted interventions for these facilities — rather than applying a single regional advisory uniformly — is a high-value equity application.

8.6 Ecological and occupational response planning

Without entering the critical-infrastructure territory of Paper 4, this paper notes two adjacent opportunities. Ecological triage — identifying where fire, smoke, and heat interact with protected areas, urban vegetation, watershed function, and ecological recovery capacity — can benefit from better fire-behavior and compound-event prediction. Occupational safety for outdoor workers in agriculture, construction, fisheries, emergency response, and delivery logistics is directly served by better local heat-smoke compound forecasts. WHO/WMO explicitly position occupational heat stress as a global societal challenge requiring immediate action, and the fire-smoke compound dimension of that exposure is not addressed by any current operational system.

9 Geographic Case Studies

9.1 Australian Black Summer 2019–20: the archetypal compound extreme event

The Australian Black Summer of 2019–20 remains the most consequensively studied compound fire-heat-smoke event in the recent global record. Between November 2019 and March 2020, approximately 18.6 million hectares burned across southeastern Australia, making it the largest fire season ever recorded on the continent to that point. Thirty-four people died directly in fire-related incidents. The Medical Journal of Australia's systematic analysis estimated an additional 445 smoke-attributable deaths, primarily from cardiovascular and respiratory disease, concentrated in New South Wales and Victoria but extending to the Australian Capital Territory and beyond.

The economic toll was severe. Deloitte Access Economics' 2021 analysis placed the total economic cost at AUD 103 billion, incorporating direct costs (property destruction, emergency response, business interruption) and indirect costs (long-term health effects, ecological damage, tourism losses, and productivity loss). This figure is almost certainly conservative relative to full social costs including mental health, community displacement, and watershed damage leading to subsequent flooding events in 2022.

The air-quality consequences were extraordinary. Sydney's air quality index exceeded the "hazardous" threshold on 81 separate days during the crisis period. Air quality in Canberra briefly reached levels among the worst ever recorded in any major city globally. School outdoor activities were cancelled for extended periods across New South Wales. Sydney's New Year's Eve fireworks event proceeded despite intense public debate about smoke-health risks to the assembled crowd.

The fire-prediction failure was structural, not incidental. Bureau of Meteorology post-event reviews noted that the unprecedented scale of fire-atmosphere interaction — including pyroconvective storms that threw burning embers tens of kilometers ahead of fire fronts, triggering new ignitions — was not captured by operational fire-behavior models. The advance warning gap was identified as three to seven days: the period during which better prediction of fire-weather severity could have enabled pre-positioning of aerial resources, earlier activation of elevated-risk community warnings, more credible early evacuation advisories for the most threatened areas, and better preparation of hospital and emergency medical service surge capacity.

Under τ assumptions, the critical improvement would be in exactly this phase: the three to seven days before peak fire-weather conditions, when more faithful modeling of fire-atmosphere coupling would produce a different qualitative picture — not "severe fire weather is possible" (which existing systems did produce) but "pyroconvective development in this corridor is probable under these atmospheric conditions, spread rates will exceed parameterized model projections, these communities are in the elevated-threat envelope, these resources need to pre-position now." That shift from possible to probable, at three to seven days rather than hours, is the value proposition in concrete operational terms.

9.2 California 2020 Fire Season and the Camp Fire Context

California's 2020 fire season set records that have since been partly surpassed but that remain instructive for the structural analysis. 4.2 million acres burned — the first time California's annual burned area exceeded 4 million acres in the modern record. Swiss Re and CAL FIRE documented USD 12.1 billion in insured losses. Thirty-one people died. More than 22,000 structures were destroyed. The smoke plume from California fires was tracked reaching Europe by NOAA's atmospheric monitoring systems, a striking illustration of the transcontinental scale of smoke as a public-health hazard.

The Camp Fire of November 2018 provides the most analytically important case study because of its documentation of the prediction failure mode. The Butte County fire, which destroyed the town of Paradise and killed 85 people, is the deadliest and most destructive California wildfire on record. Losses in Butte County reached USD 16.5 billion. Paradise, a town of approximately 27,000 people, was effectively destroyed in approximately 90 minutes.

Warnings were issued approximately six hours ahead of the fire's arrival in the town. This is not a negligible lead time — six hours is operationally meaningful. The failure was in the spread-rate prediction: behavioral fire spread moved approximately three times faster than model projections suggested. The combination of strong Diablo winds, low humidity, fine fuel load, and terrain-induced flow acceleration produced conditions in which parameterized fire-behavior models substantially underestimated the rate of advance. The result was that evacuation orders arrived ahead of the fire, but not far enough ahead given the actual spread rate, and that evacuation routes became compromised as the fire outpaced traffic.

The compound nature of the event extended to smoke. The Camp Fire produced a smoke plume that affected air quality across northern California for weeks. Schools in Sacramento — more than 150 kilometers from the fire — cancelled outdoor activities for extended periods. Hospitals across the Sacramento Valley reported elevated respiratory presentations for weeks following ignition.

Under τ assumptions, the specific improvement addressable here is in the advance characterization of spread rates under wind-terrain coupling conditions. Current operational models use pre-computed wind fields from mesoscale atmospheric models and apply simplified fire-spread physics that does not resolve the fire-atmosphere feedbacks driving extreme-spread events. A physically coupled τ twin that resolves these feedbacks would produce higher spread-rate projections for the conditions that prevailed on November 8, 2018 — not necessarily perfect prediction, but a qualitatively different risk envelope that would have warranted earlier and more urgent evacuation orders.

9.3 Greece Evros Wildfires, August 2023: the Mediterranean Compound Extreme

The Evros regional wildfires in northeastern Greece in August 2023 provide the most significant recent Mediterranean case study. A single contiguous fire complex reached approximately 96,000 hectares of burned area, making it the largest single wildfire ever recorded in the European Union by area. The Greek Evros event was not an isolated incident: it occurred during a Mediterranean-wide compound heat-and-fire episode in which Greece, Cyprus, Turkey, Tunisia, Algeria, and Italy all experienced simultaneous severe fire activity during a prolonged heat wave.

The EU Civil Protection Mechanism was activated to provide aerial firefighting support from multiple member states. The Copernicus Emergency Management Service provided satellite-based damage and burn-area mapping in near-real-time. These responses illustrate the institutional capacity that exists for response; they also illustrate its limitations for prevention and prediction.

The compound structure of the event was critical. Greece experienced extended heat wave conditions with temperatures exceeding 40°C for multiple consecutive days, combined with low relative humidity, dried vegetation from a drought-affected spring and early summer, and surface wind conditions favorable for rapid fire spread. Smoke from the Greek fires, combined with smoke from simultaneous fires in Algeria and Tunisia, created air quality degradation across the central and eastern Mediterranean basin affecting populations in multiple countries simultaneously.

For the τ deployment case, this event illustrates three relevant points. First, Mediterranean compound fire-heat events are already large enough that the EU Civil Protection Mechanism — designed for extraordinary response — is being activated for events that are on track to become more frequent and severe under climate projections. Second, the coupling between heat, drought, fire ignition, fire spread, and smoke is tight enough that a physically integrated twin would be substantially more operationally useful than separate agency-specific tools. Third, the transboundary nature of smoke from these events — affecting populations across national borders simultaneously — creates a natural case for regional platform architecture rather than purely national deployment.

Under τ assumptions, an EFFIS-complementary Mediterranean fire-weather-smoke-health twin would serve the institutions (EU Civil Protection Mechanism, Copernicus, national civil-protection agencies, national meteorological services) that already have operational mandates for this domain, providing the operationally actionable fire-behavior and compound-risk products that EFFIS's seasonal fire-danger framework and satellite mapping are not designed to deliver.

10 Finance, ROI, and Climate-Finance Eligibility

10.1 The cost suppression baseline

The economic case for investment in τ-grade wildfire-smoke-heat intelligence begins with the cost of the status quo. NIFC data show average annual U.S. federal fire suppression expenditures of approximately USD 3.4 billion per year over the past decade, with peak years exceeding USD 4.5 billion. This figure covers federal suppression costs only; state suppression costs, property losses, health costs, and the long-run ecological and watershed damages that amplify downstream hazards add substantially to the total burden.

The Black Summer's AUD 103 billion economic cost for a single Australian fire season provides a non-U.S. anchor. California's 2020 insured losses of USD 12.1 billion are a single-state, single-year figure for a system that now regularly exceeds USD 10 billion in insured losses in high-fire years. Switzerland Re's Global Insured Losses reports have consistently identified California wildfires as one of the most significant drivers of annual global insured-loss variability since 2017.

The smoke-health cost dimension adds a further large figure. EPA's Value of a Statistical Life (VSL) methodology provides a standard federal approach for monetizing mortality risk reduction: the current EPA VSL is approximately USD 11 million per statistical life. Applying this to conservative estimates of several thousand smoke-attributable excess deaths per year in the United States alone generates annual VSL-equivalent costs in the tens of billions of dollars. WHO/Europe's figure of 60,000 heat deaths in 2022, at European VSL-equivalent values, represents a mortality burden of comparable magnitude.

Against this baseline, investment in τ-grade fire-smoke-heat intelligence has a cost-benefit structure that is favorable by multiple orders of magnitude if even modest percentages of these burdens are addressable.

10.2 Cost Scenario A: National wildfire intelligence platform

A national wildfire intelligence platform deploying τ-grade fire-behavior, smoke-transport, and heat-health prediction for a single high-risk country (United States, Australia, Greece, or comparable national context) is estimated at USD 2–6 million in initial setup costs, including model adaptation, computational infrastructure, data integration pipelines, and institutional training. Annual operational costs are estimated at USD 0.5–1.5 million per year, covering cloud computing, maintenance, staff, and operational integration with incumbent systems.

The benefit-to-cost ratio for this scenario, estimated against fire suppression cost avoidance, structure-loss reduction, and smoke-health burden reduction, spans a wide range depending on the precision of the impact attribution. Conservative benefit-to-cost ratios of 3:1 to 10:1 are supportable against fire-suppression cost avoidance alone, using NIFC's average of USD 3.4 billion per year as the suppression cost baseline and assuming that even 1–3 percent of suppression costs are attributable to spread-prediction failures addressable by better physics. Including structure-loss avoided costs, smoke-health avoided costs (using EPA VSL methodology applied to PM2.5 excess mortality), and reduced evacuation overhead pushes benefit-to-cost ratios to 10:1 or higher in high-fire-damage years.

10.3 Cost Scenario B: Regional multi-country platform (Mediterranean or Southern Hemisphere)

A regional platform covering the Mediterranean basin (serving Spain, France, Italy, Greece, Portugal, and neighboring countries) or the Southern Hemisphere (Australia, New Zealand, Chile, Argentina, South Africa) would require a larger investment reflecting multi-country data integration, multilingual interface requirements, and the coordination costs of multi-national governance. Setup costs are estimated at USD 15–40 million, with annual operations at USD 3–8 million.

The benefit framing for a regional platform extends beyond fire suppression to include: cross-border smoke-health burden reduction (which, given the transboundary nature of large fire-smoke events, is inherently a regional-scale benefit); coordinated EU Civil Protection Mechanism activation efficiency; shared aerial firefighting resource optimization across national boundaries; and tourist-economy protection in Mediterranean coastal areas where fire-driven air-quality degradation has measurable tourism-revenue impacts.

A Mediterranean platform would be directly eligible for EU Civil Protection Mechanism funding for the coordination and preparedness components, with potential co-financing from Copernicus Services contracts, national civil-protection agency procurement, and EU research-and-innovation funding under Horizon Europe's climate-resilience priority.

For the smoke-health avoided-cost framing in Scenario B: applying European statistical-life values (approximately EUR 3–4 million per statistical life, lower than U.S. VSL due to EU regulatory convention) to even 5 percent of the 60,000 heat deaths attributable to the 2022 European heat episode generates an avoided-cost figure of EUR 9–12 billion in a single extreme year — substantially exceeding the total regional platform investment at any reasonable discount rate.

10.4 Named climate-finance windows

Green Climate Fund (GCF) — Resilience-to-Climate-Change Funding: The GCF's resilience funding window directly targets investments that improve climate adaptation capacity in developing and transition countries. Wildfire-prone countries in the Mediterranean, Sub-Saharan Africa, Southeast Asia, and Latin America are all GCF-eligible jurisdictions. A τ wildfire-smoke-heat intelligence platform framed as a climate adaptation investment — reducing climate-driven disaster losses and protecting vulnerable populations from compound extreme events — aligns with GCF programming criteria for both readiness grants (for platform design and institutional capacity) and project funding (for operational deployment).

World Bank GFDRR (Global Facility for Disaster Reduction and Recovery) — Wildfire Component: The World Bank's GFDRR provides grants and technical assistance for disaster risk reduction across multiple hazard families. The GFDRR has an explicit wildfire component that has supported fire-risk governance capacity building in multiple countries. A τ-grade fire-intelligence platform would be eligible for GFDRR technical-assistance funding for design and pilot phases, with potential transition to World Bank lending for full deployment.

EU Civil Protection Mechanism and rescEU Fire Fleet: The EU Civil Protection Mechanism funds preparedness and response capacity across EU member states and partner countries. The rescEU fire fleet — the EU's shared pool of aerial firefighting resources — is governed through the Mechanism and could benefit directly from better fire-spread prediction that improves resource pre-positioning and deployment efficiency. Horizon Europe's Climate Change Adaptation cluster provides research-to-deployment funding that could support τ pilot development and validation.

USAID Bureau for Humanitarian Assistance (BHA): USAID BHA funds disaster risk reduction and preparedness investments in partner countries, with a specific focus on reducing the humanitarian consequences of natural disasters. Wildfire and heat-health intelligence for fire-prone developing countries in sub-Saharan Africa, Southeast Asia, and Latin America would be eligible for BHA pre-positioning and disaster-risk-reduction programming.

UNDP Climate Resilience Early Warning System (CREWS): The CREWS initiative, jointly managed by UNDP, WMO, and other partners, specifically funds early warning and hydromet capacity development in least-developed and small-island developing countries. While wildfire is secondary to flood and cyclone in CREWS programming, the heat-health and compound-extreme dimensions of the τ wildfire-smoke-heat platform would be directly eligible where heat is a primary climate risk, including in sub-Saharan Africa and South and Southeast Asia.

11 Evidence and Translation Ladder

A realistic adoption path for τ-grade fire-smoke-heat intelligence would follow a staged progression from shadow-mode validation through operational integration to policy embedding.

11.1 Stage 1 — Shadow-mode wildfire and smoke benchmarking (Years 1–2)

The first stage runs τ in parallel with existing operational systems for wildfire spread, smoke transport, and heat risk, without displacing any current operational products. The objective is to establish transparent, independently verifiable performance comparisons across multiple fire seasons and heat events in at least one fire-prone region.

The relevant operational baselines for benchmarking include: RAP-Smoke and HRRR-Smoke for near-term smoke forecasting; RRFS-Smoke Dust for next-generation NOAA smoke guidance; FARSITE and FlamMap for fire-behavior prediction; EFFIS for European fire-danger context; HeatRisk from NOAA/NWS for heat-health guidance; and CDC Heat & Health Tracker for health-outcome context. Smoke benchmarks should include PM2.5 MAE and CRPS at 6h/24h/48h/72h horizons, plume-arrival timing error, and exposure-weighted population error. Fire-spread benchmarks should include 6h/12h/24h perimeter overlap against observed progression. Heat benchmarks should include HeatRisk category agreement, nighttime recovery risk skill, and vulnerable-neighborhood differential performance.

Pilots best suited for this stage: the California/U.S. West fire-weather corridor (strongest existing NOAA, EPA, and CDC benchmark infrastructure); the Mediterranean Europe heat-fire corridor (Greece, Spain, Portugal, France); and the Canada-U.S. transboundary smoke and boreal fire domain.

11.2 Stage 2 — Incident support and public-health pilots (Years 2–5)

In the second stage, τ moves into selected pilot domains where shadow-mode performance has been validated. The strongest candidates are: incident support for active wildfire events in California, Australia, or Greece where τ fire-behavior prediction can be used alongside FARSITE/FWI products for specific high-risk events; local smoke and cleaner-air-space pilots in urban centers with strong existing air-quality monitoring networks (Los Angeles, Sydney, Athens, Rome); worker heat-smoke protection pilots in partnership with agricultural labor organizations, construction industry safety bodies, and logistics operators in heat-affected regions; and city-scale compound heat-smoke action pilots with a major metropolitan public-health department.

In this stage, the benchmark scorecard expands from pure forecast verification to include operational decision metrics: lead time gained for evacuation orders, false-alarm reduction for smoke advisories, schools protected by earlier action, exposed person-hours reduced, high-risk worker-hours shifted to safer scheduling windows, and lives or health burdens plausibly averted in evaluated pilots.

11.3 Stage 3 — Integrated regional hazard twins (Years 4–8)

In the third stage, fire, smoke, heat, and local exposure are integrated into regional digital-twin operations serving state or provincial response centers, large metropolitan air basins, and high-risk tourism and agricultural corridors. The regional architecture enables: multi-jurisdiction response coordination; shared aerial-resource pre-positioning optimization; cross-border smoke-health advisory coordination; and metropolitan public-health systems that receive compound-risk products rather than separate fire, smoke, and heat advisories.

This stage is where τ-grade intelligence begins to change institutional operating doctrine rather than merely improving individual forecasts. Regional fire-weather operations centers, metropolitan public-health emergency operations, and cross-border civil-protection coordination all become substantively different when compound-risk intelligence is available at operational resolution.

11.4 Stage 4 — Policy and standards integration (Years 6–12)

The fourth stage uses verified τ performance, accumulated across multiple fire seasons, to inform durable policy change: heat-health action plans with local digital-twin integration; worker-protection standards with τ-informed thresholds and trigger protocols; cleaner-air-space and public-building standards tied to local smoke-forecast capabilities; multi-agency compound-extreme operating doctrine embedded in national emergency-management frameworks; and international coordination protocols for transboundary smoke events.

This stage is where the investment in shadow-mode validation and pilot operations pays its longest-run dividends — not in marginal forecast improvement but in institutional transformation that makes wildfire, smoke, and heat governance systematically more preventive and less reactive.

12 Stakeholder Map and Change Management

12.1 Primary operational adopters

National meteorological services (NOAA, Bureau of Meteorology, AEMET, Meteo France, HNMS, and others) are the primary institutional entry points for τ fire-weather and smoke-transport products, since these agencies already operate fire-weather warning and smoke-forecast services. Their institutional needs include validated forecast performance improvement, compatibility with existing warning dissemination infrastructure, and transparent error characterization. The critical change-management requirement is not replacing existing NWP systems but demonstrating τ advantage on the specific events where current systems have documented failures.

Fire and civil-protection agencies (CAL FIRE, NIFC Predictive Services, SENASA, EU Civil Protection, national civil-protection authorities) need fire-behavior prediction that is faster, finer, and more dynamically coupled than FARSITE. Their critical requirement is operational integration: outputs must be available at incident-relevant timescales (minutes to hours), must be legible to fire-behavior analysts without extensive retraining, and must be supported by honest confidence characterization that respects operational decision thresholds.

Public-health authorities (CDC, WHO regional offices, national health ministries, local health departments) need smoke and heat intelligence that is health-outcome aware, not only hazard-threshold aware. Their adoption path runs through demonstrated improvement in the precision and timeliness of public-health advisories, particularly for vulnerable populations, rather than through meteorological validation metrics.

12.2 Enabling and regulatory stakeholders

Air-quality regulatory authorities (EPA, European Environment Agency, national AQI agencies) are both users of and gatekeepers for smoke-forecast products. Their requirements include regulatory alignment with official AQI standards, formal validation of PM2.5 forecast skill, and compliance with agency advisory protocols. τ adoption in this domain requires early engagement with regulatory bodies to establish validation frameworks and to ensure that τ smoke products are eligible for incorporation into official advisory systems.

Labor and occupational safety bodies (OSHA, national labor inspectorates, WHO/ILO) are critical stakeholders for the worker-heat-smoke protection dimension. Their adoption path requires demonstration that τ compound-risk products improve trigger quality for occupational heat and smoke standards, with associated reduction in preventable worker-health incidents.

School and education systems represent a major scale opportunity. Millions of school operational decisions — outdoor recess, physical education, school opening and early dismissal — are made annually on the basis of smoke and heat advisories. Better local smoke and heat intelligence that improves the precision and timeliness of these decisions protects millions of children annually. The change-management requirement is simple: a school-appropriate compound-risk product that maps directly onto existing administrative decision protocols.

12.3 Finance and governance stakeholders

Climate-finance institutions (GCF, World Bank GFDRR, USAID BHA, UNDP CREWS) evaluate investments against formal resilience criteria. Successful τ program-officer engagement requires: clear articulation of the investment case in climate-adaptation terms; reference to the authoritative baseline statistics (WHO heat deaths, NIFC fire losses, IPCC fire-weather projections) that establish the problem scale; transparent cost-benefit framing using standard methods (EPA/EU VSL, NIFC suppression baselines); and a deployment ladder that connects investment phases to measurable outcome milestones.

Insurance and reinsurance sectors are natural clients for τ fire-weather intelligence and potential co-investors in regional platform development. Swiss Re, Munich Re, and the Lloyd's market all have documented business interests in better wildfire-risk prediction in California, Australia, and Mediterranean Europe — the same domains where τ would provide the greatest differentiated value. Catastrophe models that currently treat wildfire as a relatively non-predictable peril could be substantially improved by τ-grade fire-behavior inputs, creating commercial incentive structures that align with the public-good deployment objectives.

13 Gender, Equity, and Labor Dimensions

13.1 Heat and smoke exposure is unequally distributed

The health burden of wildfire smoke and extreme heat is not randomly distributed across populations. CDC identifies older adults, young children, people with chronic conditions, low-income communities, and unhoused populations as disproportionately vulnerable to extreme heat. NIOSH identifies children, pregnant women, and people with asthma, COPD, or heart disease as among those at higher risk from wildfire smoke. WHO and WMO identify manual workers, low-income populations, older adults, and children as especially vulnerable to heat stress.

These vulnerability categories correlate with structural disadvantage. Low-income households are more likely to live in buildings without air conditioning or adequate air filtration. Low-income workers are more likely to be employed in occupations requiring outdoor or poorly ventilated physical labor. Low-income communities are more likely to be located in urban heat island zones and in areas downwind of industrial emission sources that compound smoke exposure. Immigrant and informal workers are less likely to have access to workplace heat-protection protocols even where these legally exist.

Better hazard intelligence that cannot reach these populations does not close the equity gap — it may widen it, by improving protection for those who already have access to better information and resources while leaving behind those who do not.

13.2 Gender dimensions of heat and smoke vulnerability

Gender intersects with heat and smoke vulnerability in multiple ways that are inadequately addressed by current advisory systems. Pregnant women face elevated heat-related risks, including preterm birth, low birth weight, and gestational complications, at temperature thresholds below those that trigger public heat emergency declarations. Women are disproportionately represented in informal care work — elder care, childcare, domestic work — that often occurs in poorly ventilated home environments where smoke and heat accumulation is highest. In many contexts, women face barriers to accessing public cooling centers or modifying work schedules in response to heat advisories.

Occupational heat exposure has a significant gender dimension in agricultural settings, where women perform a substantial share of field labor in many low- and middle-income countries. Better local compound heat-smoke forecasts that enable work-scheduling adjustments, appropriate rest-hydration-shade protocols, and timely health alerts represent a meaningful gender-equity intervention in this context.

τ platform design should explicitly include: vulnerability-stratified compound-risk products that surface gender-specific exposure categories; messaging protocols accessible to women in informal and care work; and integration with gender-responsive social protection and community outreach systems.

13.3 Labor rights and occupational protection

The WHO/WMO 2025 joint guidance on worker heat stress frames occupational heat exposure as a global human rights issue, not merely a productivity question. Workers in agriculture, construction, fisheries, emergency response, outdoor logistics, and street vending face heat and smoke exposures that are neither voluntary nor compensated. Better compound-risk intelligence that feeds into enforceable labor protection standards — mandatory rest schedules, shade-and-hydration requirements, exposure-limit protocols triggered by local forecast thresholds — has direct labor-rights significance.

This is an area where τ deployment should be explicitly linked to labor-standards enforcement rather than treated as a pure information product. A τ-grade compound heat-smoke forecast that tells an agricultural labor employer a worker's exposure will exceed WHO guidelines, without an enforcement mechanism to act on that information, provides incomplete protection. The deployment architecture should include pathways from forecast intelligence to labor inspection, worker notification, and employment-standard enforcement.

13.4 Equity in the design of cleaner-air spaces and cooling centers

The distribution of publicly accessible cleaner-air spaces and cooling centers is currently driven by historical siting decisions that often do not reflect current population vulnerability or smoke/heat exposure patterns. Better local compound-risk prediction can improve the equity of this distribution by: identifying neighborhoods with highest compound heat-smoke exposure that lack adequate protective infrastructure; informing siting decisions for new public cooling centers and air-filtration facilities; enabling demand-responsive activation of protective services (cooling centers opened earlier in highest-risk neighborhoods) rather than uniform activation; and prioritizing outreach and welfare-check resources toward communities with least self-protective capacity.

This is an equity dimension where better hazard intelligence directly enables better governance without requiring complementary policy changes — only better use of existing public resources.

14 Governance Guardrails

14.1 Shadow mode and the principle of earned trust

The most critical governance guardrail for τ deployment in fire-weather-health systems is the discipline of shadow-mode validation before operational integration. Fire agencies, air-quality authorities, public-health departments, and school systems make decisions that affect lives. Those institutions cannot and should not bet public safety on any unvalidated new prediction system, regardless of its theoretical basis.

Shadow-mode operation — running τ in parallel with incumbent systems, with transparent scorecards and independent verification — is not merely a technical validation step. It is an institutional trust-building process. Official meteorological services, fire agencies, and health departments have earned their institutional mandates by demonstrating reliability over decades. τ must earn its place in those systems through demonstrated performance on the events that matter most, not through claims about theoretical superiority.

The governance implication is practical: τ deployment plans should include independent third-party verification of forecast performance, public scorecard publication, and explicit stage-gate criteria that define what level of validated performance is required before any τ product is incorporated into operational warning systems.

14.2 Avoiding false precision

Even under strong τ assumptions, compound-event prediction involves irreducible uncertainty. Wind shift timing, spot-fire initiation, smoke injection height, and overnight temperature recovery are all influenced by small-scale physical processes that no model can resolve perfectly. The governance requirement is honest confidence characterization: τ products must convey uncertainty in forms that are actionable for non-specialist users (emergency managers, school administrators, labor inspectors) without creating the impression of precision that the physics does not support.

Bounded-error intelligence is still bounded. The governance failure mode is not that τ predictions are wrong — some will be wrong — but that bounded uncertainty is communicated in ways that either paralyze action (because uncertainty is overemphasized) or create false confidence (because uncertainty is underemphasized). Calibrated, legible uncertainty communication is a technical and institutional design requirement, not an afterthought.

14.3 Public trust and communication discipline

Heat and smoke warnings are subject to alert fatigue when they are too frequent, too broad, too uniform, or too opaque. The observed pattern in many warning systems — broad regional advisories that cover populations with very different actual exposures, advisory frequency that desensitizes recipients, threshold-based triggers that activate uniformly regardless of local conditions — reduces warning effectiveness and erodes the public trust that makes effective public-health response possible.

One of the strongest governance tests for τ deployment is whether it makes warnings better for the people who receive them: more specific to actual local conditions, better calibrated to actual risk levels, more actionable in terms of specific protective steps, and more trusted because their past performance has been accurate. This requires explicit investment in warning communication design, not just forecast technology improvement.

14.4 Labor and school protections must be substantive, not nominal

As noted in the equity and labor section, the governance risk in compound heat-smoke intelligence is that better information is available to employers and school systems without a corresponding enforcement mechanism to ensure protective action. τ deployment should be paired with: enforceable labor heat and smoke exposure standards with τ-informed trigger thresholds; school and childcare protocols that are mandatory rather than advisory during compound-event conditions; indoor-air-quality infrastructure requirements that make cleaner-air-space activation practically possible; and equity-specific outreach to communities with least self-protective capacity.

14.5 Data governance, privacy, and anti-discrimination safeguards

Compound heat-smoke risk products that incorporate vulnerability data — chronic disease prevalence, building stock quality, cooling-access indicators, labor-force composition — raise privacy and anti-discrimination issues that must be addressed in platform governance. Neighborhood-level health-vulnerability data can be misused for insurance discrimination, property valuation manipulation, or selective emergency-response prioritization that disfavors high-risk-but-low-income communities. τ platform governance must include: data-use agreements that restrict vulnerability data to protective purposes; audit mechanisms for equitable emergency-response application; transparency provisions that allow community organizations to review how vulnerability data influences operational decisions; and explicit prohibition of vulnerability-data use for insurance underwriting, property valuation, or selective service withdrawal.

14.6 Multi-agency coordination doctrine

Compound events require multi-agency response, but current agency mandates are organized around single-hazard service chains. The governance requirement for a τ compound-risk platform is explicit investment in multi-agency coordination doctrine: formal agreements between fire agencies, meteorological services, air-quality authorities, labor inspectorates, school systems, and health departments about how τ compound-risk products will be used, who has decision authority for cross-domain protective actions, and how conflicting agency recommendations will be resolved during compound events.

This is not a technology problem. It is an institutional design problem that must be addressed in the governance layer rather than assumed to resolve itself once better information is available.

15 SDG Mapping and Bottom Line

15.1 SDG alignment

The τ wildfire-smoke-heat compound health protection portfolio maps directly onto multiple Sustainable Development Goal targets:

SDG 3 (Good Health and Well-Being): Reduced smoke-attributable premature mortality (3.4, 3.9); reduced heat-attributable mortality and morbidity (3.4); improved occupational health protection (3.8); strengthened health-emergency response capacity (3.d).

SDG 8 (Decent Work and Economic Growth): Improved occupational safety standards for heat and smoke exposure (8.8); reduced productivity losses from worker heat stress (8.3, 8.5).

SDG 10 (Reduced Inequalities): Equitable distribution of compound-risk intelligence and cleaner-air and cooling services to vulnerable populations (10.3, 10.4).

SDG 11 (Sustainable Cities and Communities): Better wildfire-spread and evacuation intelligence protecting urban and WUI communities (11.5, 11.b); improved urban heat island and cleaner-air-space management (11.6).

SDG 13 (Climate Action): Improved adaptation capacity for wildfire and heat as accelerating climate risks (13.1, 13.2); integration of fire-weather-health intelligence into national adaptation plans (13.3).

SDG 15 (Life on Land): Improved ecological triage and post-fire landscape management through better fire-behavior prediction (15.1, 15.3).

SDG 17 (Partnerships for the Goals): Multi-agency, multi-national coordination platforms for transboundary fire-smoke events (17.6, 17.9).

15.2 The Sendai Framework alignment

The Sendai Framework for Disaster Risk Reduction 2015–2030 provides the overarching intergovernmental framework for τ disaster portfolio deployment. The wildfire-smoke-heat portfolio contributes most directly to:

- **Priority 1 (Understanding disaster risk):** Better compound-risk characterization at local and regional scales;
- **Priority 3 (Investing in DRR for resilience):** Platform investments that reduce long-run disaster losses through better prediction and earlier action;
- **Priority 4 (Enhancing preparedness for effective response):** Multi-agency compound-extreme operating doctrine and stakeholder coordination infrastructure.

The Sendai target of substantially increasing the number of countries with national and local DRR strategies by 2030 creates a direct institutional context for τ national wildfire-intelligence platform deployment, particularly in GCF- and World Bank-eligible jurisdictions.

15.3 The IPCC AR6 imperative

The IPCC Sixth Assessment Report provides the scientific framing for urgency. Fire weather danger increases in all high-emission pathways. Heat extremes are projected to intensify and become more frequent with every increment of global warming. Compound events — heat plus drought, heat plus fire, smoke plus heat — are projected to become more frequent and more severe. Under business-as-usual emission trajectories, the hazard environment facing fire-management and heat-health systems in 2035 will be substantially more demanding than the environment those systems face today.

This means that even if the τ deployment case were assessed only against the current baseline, the investment would be justified. Against the projected 2035–2050 baseline, the investment case is stronger still: the value of better fire-smoke-heat intelligence scales with the frequency and severity of the events it is designed to address, and both are projected to increase substantially.

15.4 The bottom line

This is the breathing, working, and living paper in the Panta Rhei disaster portfolio. The other papers in the portfolio address floods, early warning systems, infrastructure continuity, and humanitarian finance — all critical. This paper addresses what it costs, in lives and health and community integrity, to live in a world where fire, smoke, and heat are simultaneously accelerating as coupled hazards.

The public-good case is among the strongest in the entire Impact portfolio. Wildfire, smoke, and extreme heat produce very large, recurring, and growing burdens of mortality, illness, displacement, lost work, and community trauma. The official system — NASA, NOAA, WHO, WMO, EPA, NIOSH, EFFIS, Copernicus — is already moving toward better integrated hazard intelligence, and the direction is exactly the one that τ would strengthen.

What is missing is not more data, more satellites, or more alert channels. What is missing is a more physically faithful, more locally trustworthy, more coherently coupled hazard twin that can turn scattered, siloed approximations into a unified compound-risk picture.

Under the strongest τ assumption, that twin would:

- improve wildfire spread prediction at the scales that determine whether evacuations succeed or fail;
- improve smoke transport and exposure forecasting at the scales that determine whether downwind urban populations receive actionable, specific protection;

- improve heat-risk prediction at the local resolution that enables cooling centers, schools, and employers to act before peaks rather than after harm;
- integrate all three into compound-risk products that enable multi-agency response to events that today exceed any single agency's capacity to manage.

The human scale of the opportunity is visible in the numbers: 60,000 heat deaths in Europe in a single year; 18.6 million hectares burned in Australia in a single season; 445 smoke-attributable deaths downwind of fires that had not reached any burning household. The τ claim is not that all of these deaths are preventable. It is that some percentage of them — hard to estimate precisely, but certainly not zero, and plausibly very large — are preventable with better compound-risk intelligence, and that the investment required to find out is small relative to the cost of not trying.

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This dossier was prepared as Paper 3 of 5 in the Panta Rhei Impact Disaster Portfolio. All τ-derived capability claims are explicitly conditional on the τ framework being physically valid and on τ-grade operational deployment having been achieved. The public-good scenarios and cost-benefit figures are planning inferences intended to frame the scale and structure of the opportunity, not official forecasts or contractual commitments. All baseline statistics are drawn from the authoritative institutional sources cited.

Source: Full manuscript text integrated from Public-Good Briefing draft.

17 Dossier accountability addendum

The following addendum records the release-facing accountability layer for this dossier: claim boundaries, baseline evidence, upstream dependencies, translation assumptions, scenario bands, scorecard rationales, benchmark requirements, governance guardrails, and related Panta Rhei surfaces. It is intentionally downstream of the full source argument above.

Impact thesis

A Public-Good Briefing on how τ could improve wildfire prediction, smoke-dispersion forecasting, heat-event warning, and compound-extreme health protection. The v3 impact thesis is conditional: a Tau-grade wildfire-smoke-heat and compound-extreme health-protection twin would become valuable if it improves benchmarked public decisions while preserving transparent uncertainty, reviewability, and governance control.

17.1 Public-good burden and baseline evidence

A Public-Good Briefing on how τ could improve wildfire prediction, smoke-dispersion forecasting, heat-event warning, and compound-extreme health protection. The public-good burden is treated here as an institutional decision problem: existing agencies already monitor parts of the domain, but the operational handoff from data to timely, auditable action remains incomplete.

17.1.1 External evidence baseline

- **UNDRR**, Global Assessment Report on Disaster Risk Reduction [6]: disaster-risk baseline.
- **WMO**, State of the Global Climate [7]: hazard and climate-extreme baseline.
- **OCHA**, Global Humanitarian Overview [4]: humanitarian need and response baseline.
- **IFRC**, World Disasters Report [3]: disaster-response institutional context.
- **World Bank Group**, Disaster Risk Management [8]: public-sector disaster-risk finance context.
- **Anticipation Hub**, Anticipatory Action Knowledge Platform [1]: anticipatory-action practice baseline.

17.2 Current institutional landscape

The relevant landscape includes public agencies, research infrastructures, standards bodies, development-finance channels, and domain review communities represented in the evidence base, including Anticipation Hub, IFRC, OCHA, UNDRR, WMO, World Bank Group. These references are evidence and adoption surfaces, not endorsements or deployment partners.

17.3 Capability gap

The practical gap is a benchmarkable translation gap: current systems expose useful data or partial models, but they do not yet provide a single law-faithful, bounded-error decision layer for wildfire-smoke-heat and compound-extreme health-protection twin.

17.4 Tau framework dependency map

Surface	Role in this dossier
Build the Tau-Kernel	finite address and scalar foundation
Recover Core Mathematics	mathematical bridge and model interface
Derive Physics	physical readout and domain translation candidate
Results lane	upstream consequences to be mapped precisely during release preparation
direct-registry-mapping-withheld	no direct Registry object is asserted until a substantive Corpus mapping is available
public-docs-mapping-withheld	TauLib module links are asserted only where public documentation exposes a clear surface
Release Manifest	release baseline
Predictions and Falsification	empirical accountability route

17.5 Translation assumptions and missing engineering

Required domain model: **wildfire-smoke-heat and compound-extreme health-protection twin**.

First benchmarkable test: fire-weather, smoke exposure, heat-risk, and public-health alert quality against official warning and health-outcome records.

- domain-specific model construction
- data ingestion and validation
- benchmark harness
- pilot protocol
- independent review workflow

17.6 Impact mechanism chain

Public-good burden → external evidence baseline → τ capability hypothesis → upstream Results / Corpus / Verify dependency → translation assumptions → benchmarked pilot → governed adoption pathway.

17.7 Scenario bands

Band	Scenario summary	Confidence
Conservative	A narrow shadow-mode pilot improves one bounded decision task for Wildfire, Smoke, Heat, and Compound-Extreme Health Protection without operational authority.	medium
Realistic	A reviewed prototype strengthens several public-sector workflows for Wildfire, Smoke, Heat, and Compound-Extreme Health Protection after benchmark comparison with incumbent systems.	medium-low
Optimistic	A reusable public-good intelligence layer becomes plausible for Wildfire, Smoke, Heat, and Compound-Extreme Health Protection after external validation and transparent governance review.	low

17.8 Impact scorecard

Public-good scale	5/5	The affected public-good burden is large or institutionally significant within the portfolio.
Tau fit	4/5	The proposed pathway depends on coupled state, bounded uncertainty, and compositional modelling rather than isolated prediction alone.
Evidence proximity	5/5	The evidence base is anchored in public institutions, official monitoring systems, or established scientific reviews.
Measurability	4/5	A first benchmark can be framed against incumbent public datasets, institutional records, or operational decision metrics.
Adoption readiness	3/5	Adoption remains conditional on domain review, governance fit, data access, and institutional integration.
Equity leverage	5/5	The pathway can prioritize underserved or vulnerable populations where public access and safeguards are built in.

17.9 Candidate pilot pathways

compound-extreme early-warning pilot with meteorological, public-health, and emergency-response agencies

17.10 Benchmark suite and success metrics

Type	Incumbent baseline	Required Tau benchmark	Success metric	Validator
translation benchmark	current public or institutional systems in the domain	fire-weather, smoke exposure, heat-risk, and public-health alert quality against official warning and health-outcome records	pre-registered accuracy, latency, uncertainty, or decision-quality metric	independent domain reviewers
governance benchmark	existing audit, disclosure, and reporting practice	transparent assumption, data, model, and failure-mode disclosure	reviewable evidence pack and adverse-outcome protocol	public-sector or expert governance panel
equity benchmark	current access, service-quality, or exposure disparities	documented pathway for underserved or vulnerable users without hidden exclusion	distributional benefit and risk review before pilot expansion	equity, community, or public-interest review process

17.11 Governance and risk guardrails

- Human oversight for any operational use.
- Public benchmark disclosure before institutional adoption.
- Equity access review for underserved or vulnerable communities.
- Data-rights and privacy controls for operational datasets.
- Misuse-prevention and adverse-outcome monitoring.
- Adverse-outcome monitoring with a documented escalation path.
- External domain review before pilot expansion.

17.12 Related Results / Corpus / Verify / Publications

This dossier is downstream of Results, Corpus, Verify, and Publications surfaces. It is not a Registry object. Direct Registry or TauLib links are asserted only where the mapping is substantive rather than decorative.

17.13 Bibliography and external evidence

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Panta Rhei Research Program

Public-Good Impact Dossier

τ for Wildfire, Smoke, Heat, and Compound-Extreme Health Protection

Dossier ID: PGID-DISA-04 Portfolio: Disaster Release: May 2026
publication-ready release

Conditional scenario map. Domain review pending. Deployment, product, validation, certified-impact, and policy-commitment claims are not made.

Public contact and review routes

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