CALIFORNIA ENERGY COMMISSION

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Biomass Potentials from California Forest and Shrublands Including Fuel Reduction Potentials to Lessen Wildfire Threat

CONSULTANT REPORT

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1.0 EXECUTIVE SUMMARY

The Fire and Resource Assessment Program (FRAP) of the California Dept. of Forestry and Fire Protection (CDF) conducted an assessment of forest and shrub biomass resources in California to evaluate the distribution and potential quantities of biomass that can be used for energy production, and the associated potential public benefits of biomass operations on reducing risks to people and resources from wildland fire. Sources of biomass for energy generation are: logging slash (branches, tops, and other materials removed from trees during harvest); lumber mill waste (sawdust, planer shavings, and trim ends); forest thinning (either for wildfire threat reduction, ecological purposes, or stand improvement); and standing shrub biomass. FRAP calculated total and annual non-merchantable biomass potentials—that portion of standing biomass not commercially viable for use as wood products—for gross standing, technically available (not excluded from extraction by administrative, regulatory, or physiographic constraints), and WUI and non-WUI portions of fire threat treatment area (where houses are at risk from wildfire). The non-merchantable component of average timber harvest for years 1999 - 2003 is also calculated. Biomass volume in bone dry tons (BDT), power generation capacity in megawatts of electricity (MWe), and energy in megawatt-hours per year (MWh/y) are quantified by major landowner class and county.

Using the latest forest inventory statistics and current spatial datasets of vegetation, FRAP estimates non-merchantable Gross standing biomass volume for forest and shrub combined to be 1.32 billion BDT. Non-merchantable, Technically available biomass totals 698 million BDT. Annual electrical power generation capacity from non-merchantable Gross standing biomass currently exceeds 4,602 MWe with more than 3,825 from forest materials, and 777 MWe from shrublands. The non-merchantable annual Technical resource generation potential is 2,454 MWe, where 2,048 MWe is from forestlands, and 406 is from shrublands.

Biomass potential in areas determined to be in critical need of Fire Threat reduction total 103 million BDT. Annual non-merchantable biomass potential totals 3.1 million BDT, with 2.7 million BDT coming from forestlands and 0.4 million BDT from shrublands. Of these totals, FRAP estimates that new product materials not currently captured by wood products manufacturing represent 4.2 million BDT/y, which translates into an electrical capacity of 753 MWe and an energy potential of 5.6 million MWh/y. Of these totals, Wildland-Urban Interface (WUI) areas, where significantly high risks from wildfire are posed to people and property, represent annual biomass potentials of 1.0 million BDT/y, 182 MWe, and 1.3 million MWh/y of energy potential.

2.0 INTRODUCTION

Previous work exploring biomass potentials for energy production suggested that by 2017, technical generation potential (i.e., the portion of the gross biomass pool likely available for utilization) could exceed 6,500 MWe, representing 11% of projected statewide peak power capacity. Existing and planned biomass power generation capacity in the state is currently 924 MWe including solid-fueled combustion power plants and engines, boilers, and turbines operating on landfill gas, sewage digester gas, and biogas from animal manures. Current total biomass capacity is 1.8% of statewide peak power capacity (51,000 MWe). Incremental capacity additions (exclusive of existing and planned generation) could exceed 2,600 MWe based on the current resource and 5,600 MWe by 2017 given resource growth and improvements in average conversion efficiency. Electrical energy contributions in 2017 (49 TWh) could reach 15% of statewide consumption (334 TWh), indicating biomass may play a significant role in state energy needs (California Energy Commission 2004).

Various estimates of the contribution of forest and other wildland biomass components to these total statewide pools have been recently developed. For example, Springsteen (2000) estimated a total annual Gross potential biomass from forest residues of 13.8 million BDT, where 5.5 million BDT came from mill waste, and 8.3 million BDT came from slash and thinnings. The estimated portion of this Gross potential available was 3.9 million BDT, determined based on recent harvest activity. Estimates of annual biomass potential from chaparral (shrubland) vegetation was 7.7 million BDT for Gross potential, and 0.8 million BDT in available potential, thus yielding total wildland biomass estimates of 21.5 million BDT Gross and 4.7 million BDT Available (Springsteen 2000).

More recent work on forest/wildand biomass associated with the above California Energy Commision Report estimates current Gross available biomass sources from forestry are estimated at 15 million BDT total, 7 million BDT of which were estimated as Technically available. Based on these figures, Gross electrical generation potential from forestry biomass is estimated at 1,800 MWe (California Energy Commission 2004). Through 2017 the largest resources for development will be municipal solid waste, in-forest biomass, animal manures, landfill gas, orchard and vineyard residues, and field crop residues. State biomass resources were viewed as sufficient to supply a substantially larger amount of renewable electricity than is presently generated as well as serving as feedstock for biofuels and bioproducts. (California Energy Commission 2004).

In this analysis, we estimate forestry/shrubland biomass standing pools and calculate annual yields based on management scenarios of utilization. We assign biomass into various components consisting of residual material from logging operations (logging slash), biomass from forest thinning, lumber mill residue, and shrub (chaparral) biomass. Biomass from the first three categories is in use today to fuel boilers which produce steam for electrical energy production. Shrub biomass utilization is not currently well developed. Estimates of biomass weight, energy and capacity reflect currently available forest inventory and shrub land. In this paper we also continue to differentiate *Gross* potential based on total inventories for all lands from that which we consider to be technically available (in this report labeled *Technical*) based on physical constraints on harvesting machinery (e.g., steep slopes), land use regulations and administrative

designations (e.g., parks, wilderness areas, zoning restrictions), and demand and supply in the forest products industry.

This paper also explores public benefits that forest biomass potential may realize when biomass utilization is strategically linked to removal of vegetation fuels that constitute wildfire-related risks to natural resources, public safety, and private property. We use a combined index of expected fire behavior (hazard) and expected fire frequency (fire probability) to stratify areas of relative *Fire Threat* (FRAP, 2003a)**,** and model biomass treatment scenarios on lands with significant Fire Threat to explore the public benefit opportunities that biomass operations may play in managing fire risks on wildlands.

3.0 METHODOLOGY

3.1 Biomass Components for Energy Production

Forestry biomass comes from two major biological sources: forests (trees) and shrublands (sometimes referred to as chaparral). The portion of forest biomass suitable for energy production consists of: harvest residues (logging slash); lumber mill residues; and material removed during forest thinning operations to improve forest stand health and fire resistance. Currently, forest biomass is used commercially as a boiler fuel for power generation. Commercial use of shrubland for energy production has not materialized to date. The following definitions are adapted from the Public Interest Energy Resources publication (2004) "An assessment of biomass resources in California:"

Logging slash: Slash comprises branches, tops, and other materials removed from trees during timber harvest. Slash excludes the tree stem or "bole," defined as from a one-foot stump to a four inch diameter top. Because the volume of slash is directly proportional to logging activity, slash as an energy resource has declined considerably in the state over recent years. Slash left on the ground after harvest can be a substantial source of surface fuels which can carry wildfire.

Forest thinnings: Thinning refers to silvicultural treatments designed to reduce crowding and enhance overall forest health and fire resistance. Thinning of forest and shrub lands by mechanical means (other than by prescribed fire) is often emphasized when the intent is to reduce the threat of catastrophic wildfire near houses or other vulnerable assets and where air quality is a concern. Thinning may or may not produce merchantable saw logs (close to half of which may end up as mill waste). *Thinnings* are the non-merchantable components extracted during harvest activities and include understory brush, small diameter tree boles, and other material transported to the mill that cannot produce sawlogs.

Mill wastes: Mill wastes are a byproduct of the milling of sawlogs, which consists generally of softwood tree boles with a diameter at breast height (dbh) of about ten inches. Mill wastes include sawdust, planer shavings, trim ends, and wood from other mill operations. Not all such residues are available for electric power generation to the grid because these materials have long been used for steam and power generation at the mill site. The resource ebbs and flows with domestic logging activity, and imports and exports have a small impact on availability as well.

Shrub: Shrublands, or chaparral, refers to woody evergreen plants adapted to the semi-arid desert regions of California (especially in the south). Shrublands range over a large area but so far there has been little development of this biomass for energy. Because shrub biomass has no current commercial value, it is only available as an energy resource through habitat improvement activities (such as thinning) or fuel treatment operations designed to reduce wildfire risks.

3.2 Forest Inventories and Shrub land data

Data from forest inventories describing vegetation structure on forested lands is the source of estimates of forest biomass weight in bone dry tons (BDT), electrical power generation capacities in megawatts (MWe) and energy in megawatt-hours per year (MWh/y). For shrub biomass estimates, maps of fuel model types (Anderson 1982) provide a basis. Forest and shrub land biomass estimates are placed into a Geographic Information System (GIS) based map and combined with other spatial datasets (e.g., slope, land cover, ownership, fire threat, wildland urban interface, etc.) to quantify standing and annual availability of biomass volumes, identify technically available lands, and prioritize treatment areas and scheduling options.

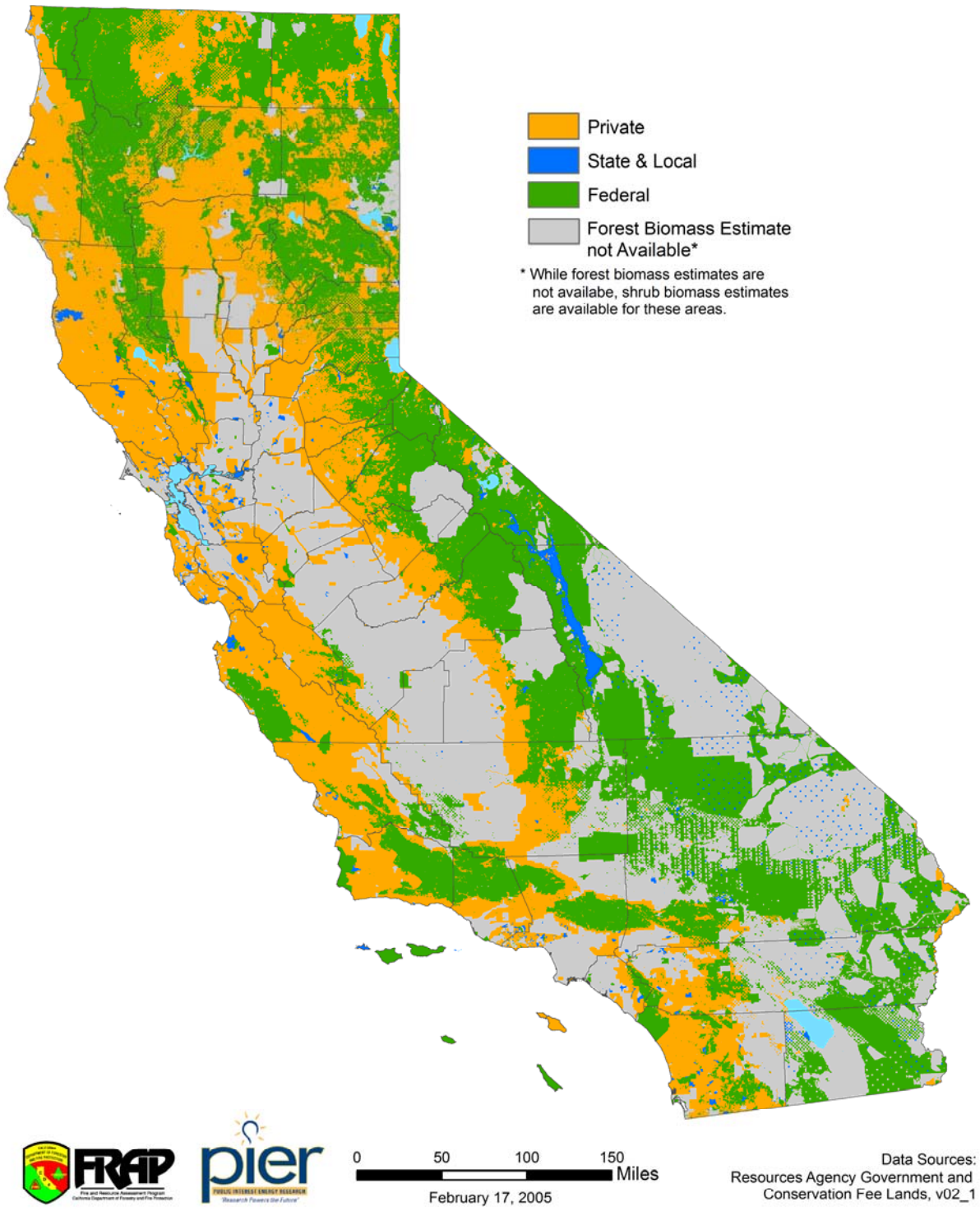
3.2.1. Forest Biomass Inventory

For privately-owned lands (i.e., outside of national forests and reserved areas such as National Parks) and some lands administered by the Bureau of Land Management, the amount of tree biomass is determined from forest measurement data captured by the Forest Inventory and Analysis (CA-FIA) program of the Pacific Northwest Research Station USDA Forest Service (Region 5). The CA-FIA is a plot-based sampling system for capturing information about trees (species, basal area, diameter at breast height, etc.) and includes data processing methods for calculating cubic foot volume, board feet, and biomass weight (USFS 2002). Sampling for this database occurred during the period 1991-1994 (Waddell and Bassett 1996; 1997a; 1997b; 1997c; 1997d).

For the national forests and their reserved lands such as wilderness areas, tree biomass data comes from the R5-FIA forest inventory. Plot data was collected mostly over the period 1996-2000 under the guidance of the Remote Sensing Lab of the Pacific Southwest Region of the USDA Forest Service (Region 5) (USDA Forest Service 2004a). A map showing the ownership distribution relative to sample data for estimating biomass is shown in Figure 1. Summary results are organized by Federal, Private, and State/Local groupings. Assumptions were based on Forest Service and non-Forest Service ownership as outlined above.

National Parks and other non-National Forest reserves were not included because forest inventory data is not readily available for these lands, and biomass extraction would likely be limited due to land management policies. Although some individual parks may have inventory based data, concerns over consistency of the data across parks, as well as the difficulty in gathering and developing a working knowledge of these data was beyond the scope of this project. Sample data could have been extrapolated from other locations, but the results could not be verified and do not provide a rigorous statistical sample. The omission is inconsequential because such lands are off-limits to timber harvest, and vegetation management for fire control is usually limited to prescribed burning as it is cheaper, more ecologically favorable, and there are few structures that can be threatened.

Figure 1. Ownership



Data obtained from the FIA plots is translated into tree information, and then into biomass weight via volume to mass conversions factors. For mapping, weighted plot per-acre average biomass is summed within map strata and then converted to a weighted average per-acre BDT for the stratum. The Forest Service Region 5 FIA Handbook provides details on use of plot weights, averaging methods, and other criteria for summarizing inventory data (USFS 2002).

Strata definitions for private lands and on four southern forests[1] use the California Wildlife Habitat Relationships (CWHR) system, developed by the California Department of Fish and Game (DFG Interagency Wildlife Task Group 2001). On northern national forests, the Region 5 vegetation classification system is used (USDA Forest Service 2004b). The decision to use CWHR rather than Region 5 strata on the four southern forests was prompted by the need to ensure an adequate number of plots in each stratum for statistical validity, and because inventories in the CDF database are slightly older than those used for current USFS inventory stratification on those forests.

3.2.2. Shrub Biomass Inventory

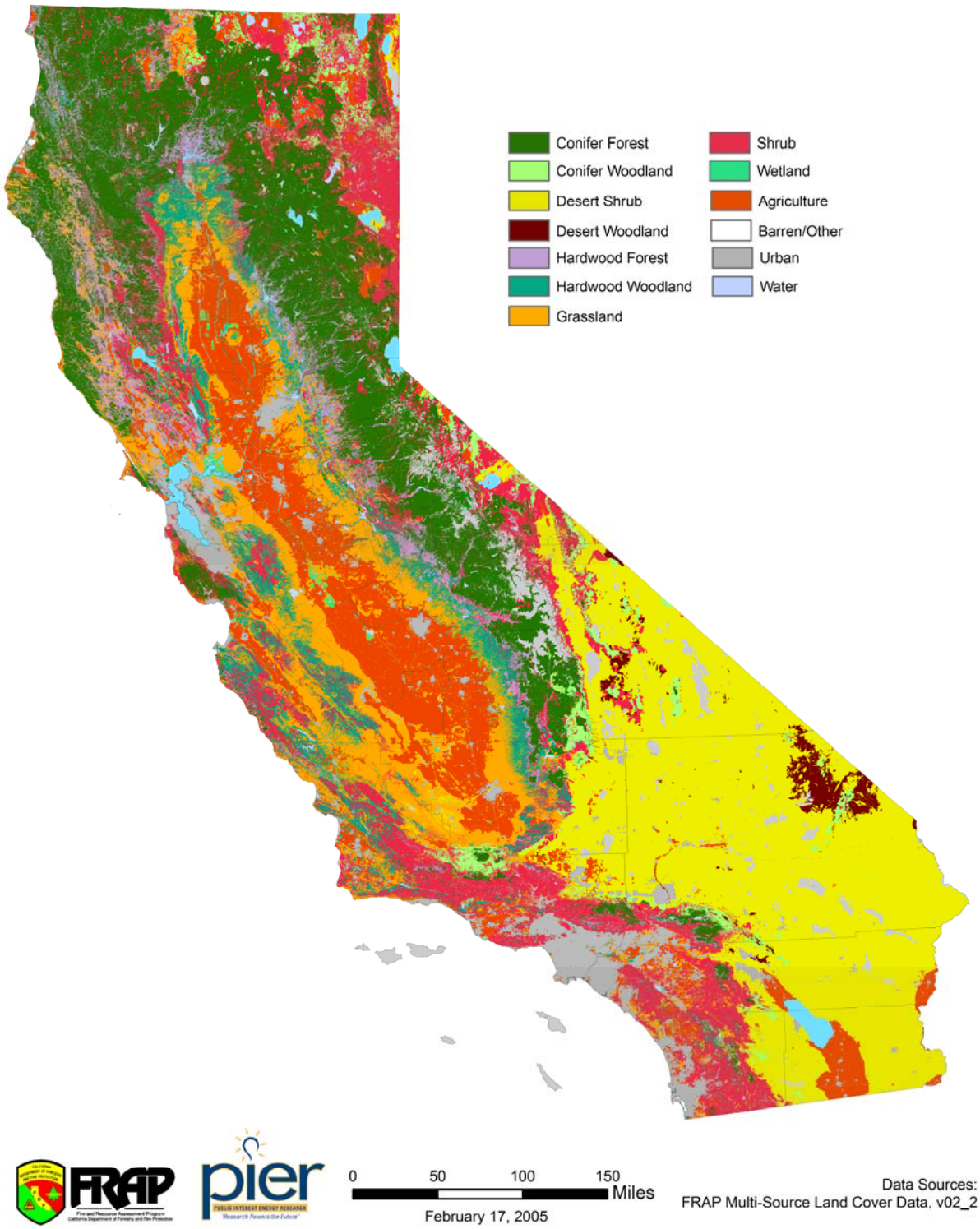
To determine the biomass volume of shrublands, Shrub and Desert Shrub classes from the FRAP Multi-source Land Cover dataset (FRAP 2002a, Figure 2) are overlaid onto CDF Fuel Model data (FRAP 2003a) to assign specific Gross biomass/acre values using data from Anderson (1982). These standing biomass values are shown in Table 1.

Table 1. Gross biomass potentials by surface fuel model type

Fuel Model	DESCRIPTION	BDT/AC
1	Grass	0.7
2	Pine/Grass	4
3	Tall Grass	3
4	Tall Chaparral	16
5	Brush	3.5
6	Dormant Brush	6
7*	Rough	4.9
8	Hardwood/Lodgepole Pine	6
9	Mixed Conifer Light	3.5
10	Mixed Conifer Medium	12
11	Light Slash	11.5
12	Medium Slash	32.5
13*	Heavy Slash	58.1
14*	Plantation/Burned last 15 years	3.5
15	Desert	1.8
28	Urban	0
97	Agricultural Lands	0
98	Water	0
99	Barren/Rock/Other	0

[1] Los Padres, Cleveland, Angeles and San Bernardino National Forests
* not presently mapped to any shrub area in California

Figure 2. Land Cover



3.3 GIS Data and Analysis Environment

Spatial analysis is conducted using Environmental Systems Research Institute Geographic Information System (GIS) software ArcInfo and GRID (v8.x and 9.0) on Sun UNIX platforms running Solaris 8.0 and ArcGIS (v8.x and 9.0) and on Dell workstations running Microsoft Windows XP.

Vector (polygon) datasets are converted to raster format using a common 100m x 100m grid cell matrix in Teale Albers Equal Area NAD 27 projection. GIS data used or created for this project are referenced throughout this document, and full citations can be found in the References section.

3.4 Biomass Potentials

FRAP organizes biomass potentials into a conceptual framework that represents the type of biomass material and its availability on the land (Figure 3).

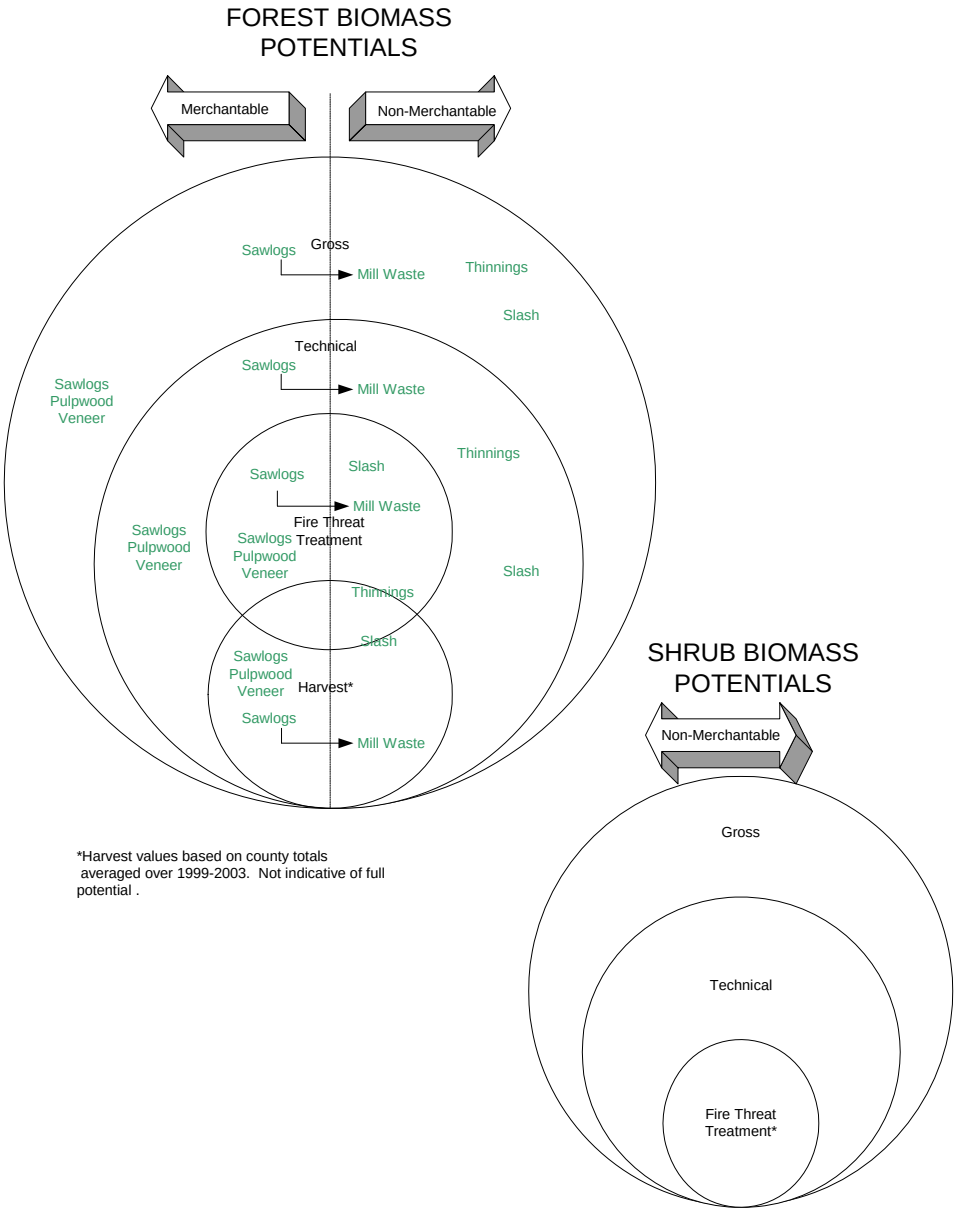
All potentials consist of two components: merchantable and non-merchantable.

Merchantable: Merchantable biomass is that portion of forest biomass from timber that is part of a tree's stem (or bole) with monetary value; usually referring to veneer, sawlog and pulpwood. Biomass from forest inventories is often reported for trees larger than 5 inches DBH, however, FRAP estimates include trees as small as one inch DBH (saplings). Logs for processing into sawn timber (sawlogs) are typically over ten inches DBH.

Non-merchantable: Non-merchantable forest biomass is that portion unsuitable for milling and presumably available for energy production. Non-merchantable biomass consists of materials left on the ground after harvest (forest slash); shrubs and small trees removed for fuels treatment, stand improvement, and forest health enhancement (thinning); and byproducts of timber mill operations (mill waste). Mill waste, because it is a byproduct of the merchantable component, is calculated as a proportion of timber harvest volume and is indicated in Figure 3 with an arrow pointing from "sawlogs" in the merchantable component to "mill waste" in the non-merchantable component.

The merchantable/non-merchantable distinction is not relevant for shrub because it has no commercial value aside from energy production and is therefore considered entirely non-merchantable (Figure 3).

Figure 3. Conceptual framework for forest and shrub biomass potentials



- Gross potential represents the entire standing biomass within California.
- Technical potential represents biomass available for removal considering topography (slope constraints), and legal/regulatory limitations on access.
- Fire Threat Treatment Area (FTTA) represents the technically available biomass that, if removed, could reduce the wildfire risks to natural and social resources.
- Harvest potential represents the 5-year average biomass generated from current timber harvest activities.

Gross Potential: Total above-ground biomass from live trees and shrubs constitutes the entirety of forest and shrub biomass available in the State (FRAP 2005a). These values are free of any technical constraints such as administratively withdrawn areas, inaccessible terrain, or sensitive habitats. While much of this potential is unlikely to be used for energy production, forest and shrub gross potential is calculated for completeness. Although annual harvest yield streams of the Gross potential are not likely, for annualization purposes of this analysis, privately owned forests have a 70-year rotation while public lands have a 100-year rotation. In addition to these rotation assumptions, the calculation of annual gross potential on non-USFS lands assumes two commercial thinning/fire threat reduction entries, one at 25 years and one at 50 years and one commercial thinning/fire threat reduction prescription is assumed at 67 years on USFS lands. This assumption serves to mimic potential biomass flows coming from active forest management as well as potential fire threat reduction entries. Table 2 identifies the percent of total trees taken by diameter at breast height (DBH) under the commercial thinning prescription assumptions. A 20-year rotation on shrub lands is a typical period for regeneration to significant levels of biomass and associated fire threat. There is no commercial thinning prescription assumption in the annualization for shrub biomass potential since shrub is generally not considered to be a commercially viable resource. A map showing the Gross potential extent is shown in Figure 4 (FRAP, 2005a).

Table 2. Commercial Thinning and Fire Threat Prescriptions (Percent of total tree biomass taken, by tree diameter class)

Diameter (inches) at Breast Height	Tree Volume Taken
Less than 9.0	90%
9.0 -11.9	50%
12.0 –14.9	20%
15.0 and greater (private land only)	5%
15.0 to 29.9 (national forests)	5%

Technical Potential: Not all biomass, merchantable or non-merchantable, is physically or administratively available for harvest. Areas excluded from the gross potential include the following:

- national forest lands with slopes greater than 35% slope;
- private and other public forest lands with slopes greater than 30%;
- stream management zones (200 ft. on either side of streams);
- coastal protection zones (indicated by zone lines);
- coastal sage scrub habitats; and
- reserves.[2]

A map of Technical Potential extent is shown in Figure 5 (FRAP 2005b). To annualize these data we assume that private owned forests are entered for commercial thinning every 25 years, with a final rotation harvest no more frequently than once in 70 years. On public lands, a single commercial thinning entry at 67 years is assumed with a final rotation harvest no more frequently than once every 100 years. These assumptions are

[2] Reserves include wild and scenic river areas, wilderness areas, USDA Forest Service special interest areas and research natural areas, private reserves, state parks, BLM reserves, national parks, and Dept of Fish and Game and US Fish and Wildlife Service game preserves

reasonable given the way private forestlands are managed, and that harvesting has diminished on national forests in recent years as greater emphasis has been placed on fire threat reduction. A 20-year rotation on shrub lands is a typical period for regeneration to pretreatment hazard levels.

Fire Threat Treatment Area (FTTA) Potential: The economic demand for biomass utilization can be augmented by realizing public benefits arising from strategic forest thinning. Within the area of Technical potential are areas where forest fuel volumes have accumulated to ecologically unstable levels and pose elevated risks from wildfire. FRAP developed a composite map, which is called Fire Threat, that combines expected fire behavior with expected fire frequency to stratify overall fire risk to various resources and assets (FRAP 2003b). A map of Fire Threat is shown in Figure 6. Additional thinning/fuel removal in these areas would reduce potential ecological damage, fire suppression costs, damages to structures and other infrastructure, and risks to public safety.

Following current fuel management policy targeting specific areas of risk to people and property, the fire threat treatment area is composed of two elements: areas inside and outside of the Wildland-Urban Interface (WUI) that have High, Very High or Extreme Fire Threat. CDF defines WUI as the intersection of two buffers─ a variable cost-function buffer ranging from 800 to 2400 m around significant fire threat and a 2400 m buffer around developed areas[3] (FRAP 2003c) (Figure 7)[4]. This intersection includes both the *in situ* fire threat itself as well as the developed area. As defined, the WUI portion of the fire threat treatment area reflects potential fire threat mitigation plans for fuels reduction (FRAP 2003c).

For this scenario, FRAP assumes the FTTA area owned by State, Local, or private owners could be treated over a period of 25 years, and that FTTA on USFS lands could be treated in 67 years. Additionally, FRAP assumes that half of the land to be treated in the FTTA will be within the WUI until that area is fully treated (about 22 years on private lands). For the remaining 3 years in the treatment period, all treatments will occur outside of WUI (but within the treatment area). A map showing the FTTA, both within and outside WUI is shown in Figure 8 (FRAP 2005c).

[3] Significant Fire Threat is defined as High, Very High or Extreme. Developed areas are those with housing densities of one or more units per 20 acres.

[4] The WUI includes the zone through which fires may spread to development from areas of High, Very High, or Extreme fire threat either by burning through, or spotting over, areas of Moderate or Non-fuel. Because fuels treatment is focused on the *in situ* threat, the fire threat treatment area does not include areas of Moderate or Non-fuel.

Figure 4. Gross Potential Areas

Figure 5. Forest and shrublands technically available for biomass production

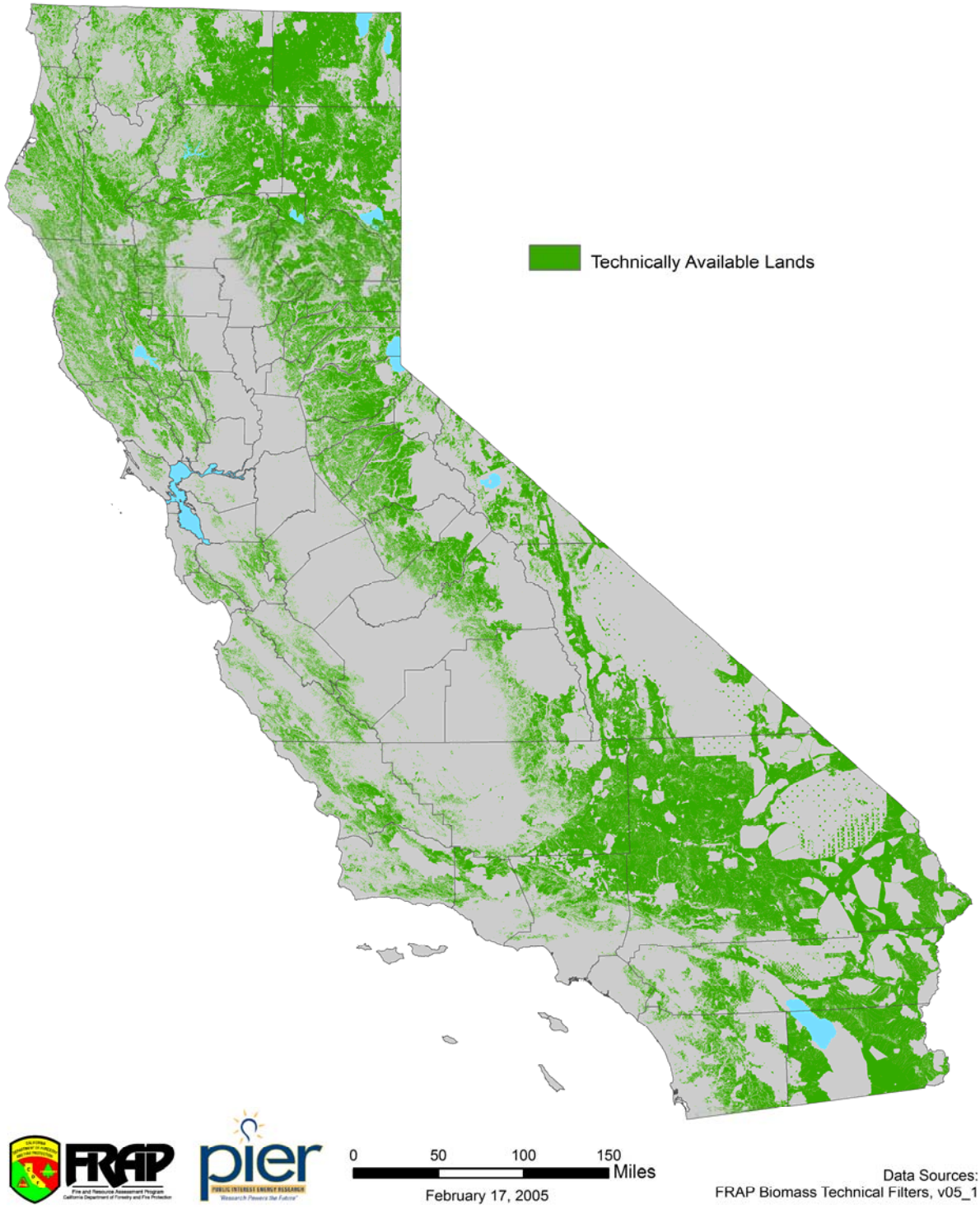


Figure 6. Fire Threat

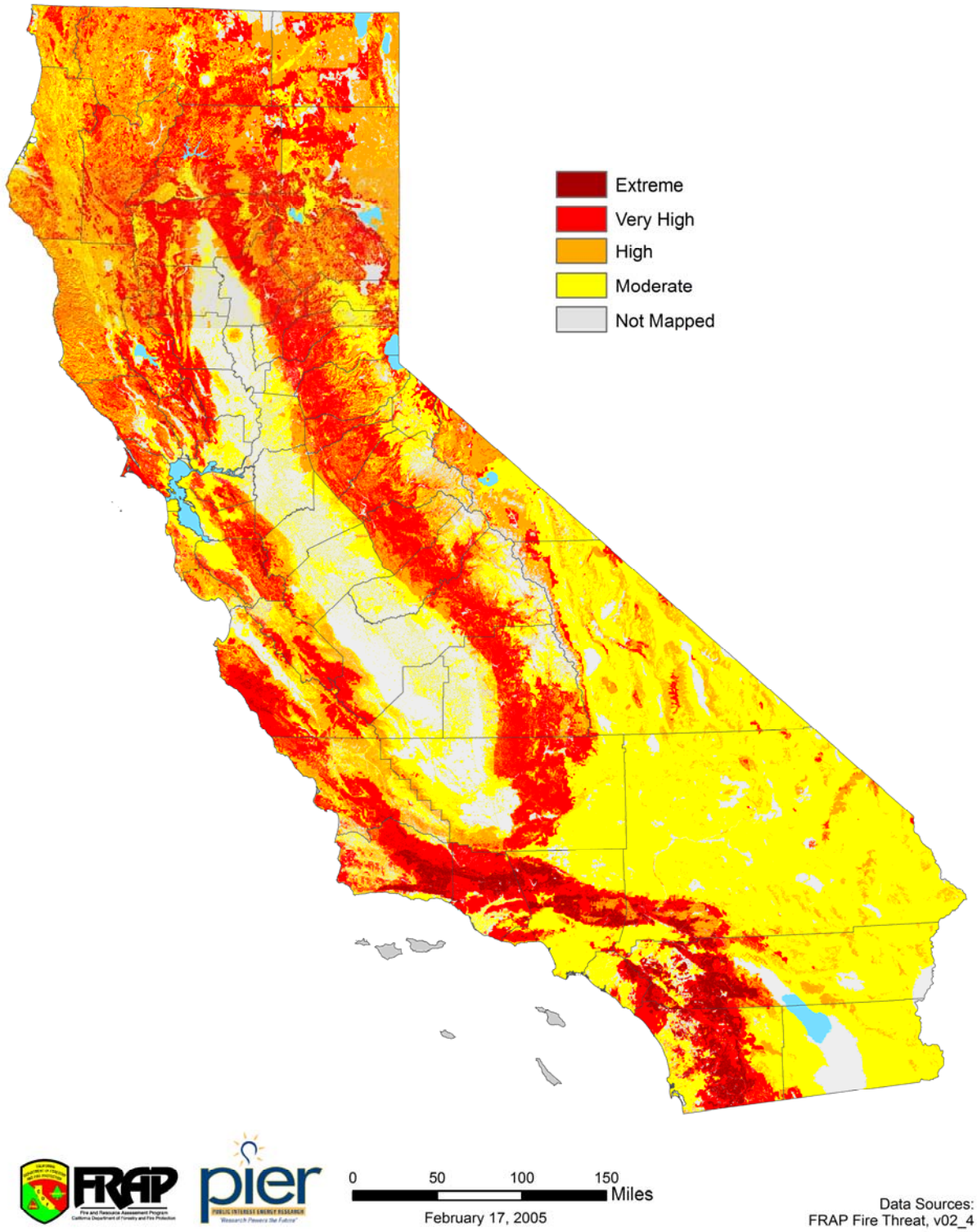
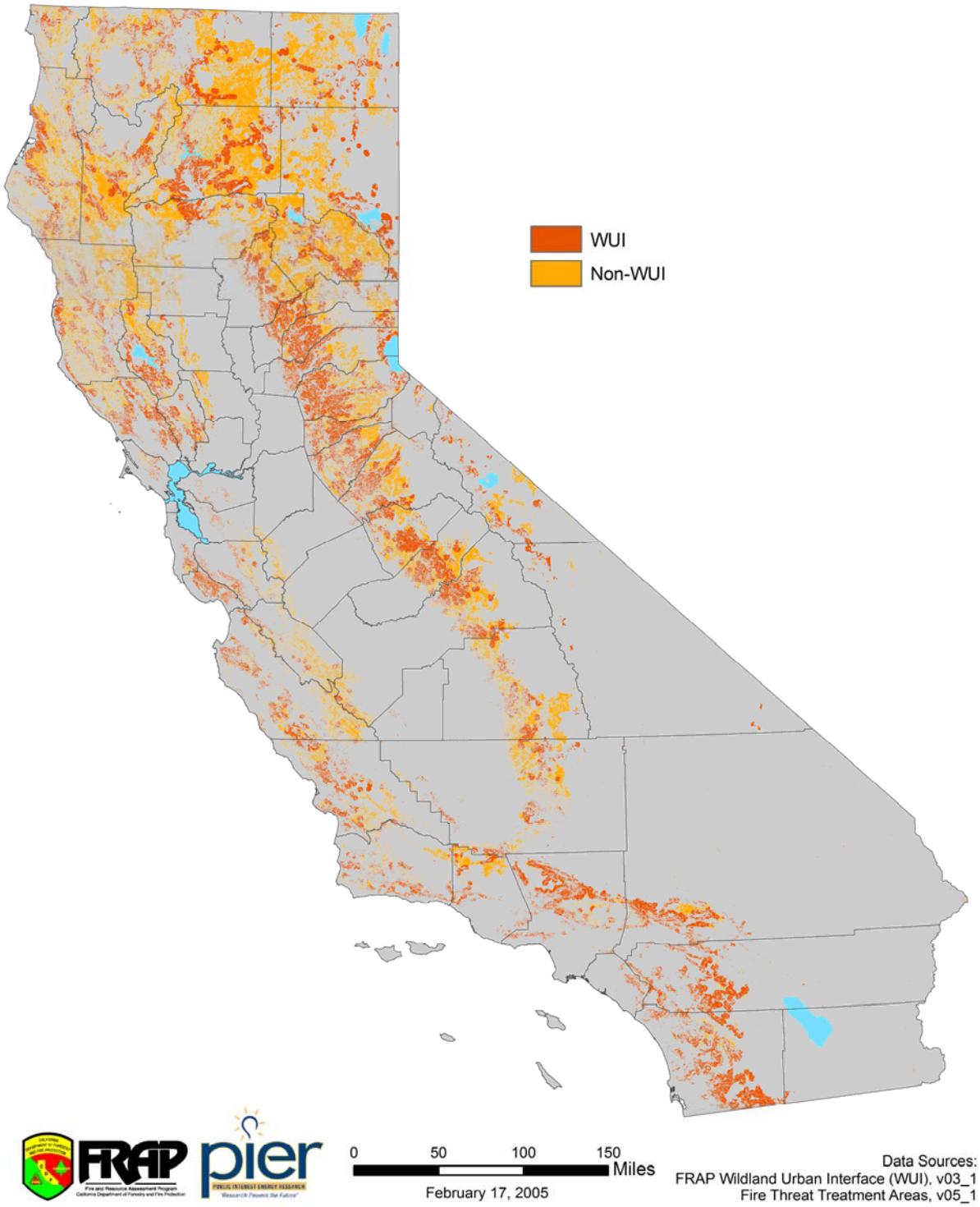


Figure 7. Wildland-Urban Interface (WUI) Areas

Figure 8. Fire Threat Treatment Area (FTTA)



The forest biomass to be taken from the treatment area is not limited to merchantable timber. Rather, thinning prescriptions target specific fractions of tree volumes based on diameter at breast height (Table 2). The nature of this treatment prescription is designed to accomplish two related goals: thinning to improve forest health, and to reduce significant forest fuels in the lower strata that provide linkage between surface and canopy fuels, thus reducing the potential of crown fire. Thinning is assumed to occur at a rate of 1.5% per year on national forests (67 year rotation) and 4% per year on private lands (25 year rotation), both of which are consistent with current state and federal fire management policy, but have yet to be implemented. The scheduling follows the general policy outlined in the recent Sierra Nevada Forest Plan Amendment Record of Decision (USFS 2004c) for Federal forested lands as well as policy direction for private lands (CDF 1996).

To help focus on the most economically suitable areas for energy production from the FTTA, and to locate potential energy production facilities, FRAP identifies the locations of highest potential biomass from the FTTA. Zones of highest potential biomass concentration were determined by summing the *in situ* biomass values from the FTTA within a 25-mile radius of each 100 meter cell on the landscape (see Results: Figure 11). The 25-mile radius roughly reflects the service area that would feed a production facility.

For shrub biomass, all treatment is considered to take place only in areas of High, Very High or Extreme fire threat *within* the WUI. The thinning prescription is presumed to be 100% (all material is removed) over a 20 year rotation on private land and a 67 year rotation on national forest land. Of this volume, only 70% of shrub biomass is recoverable for energy production due to collection difficulties and inefficiencies.

Harvest Residue Potential: In addition to forest thinning for fire threat reduction, slash from commercial timber harvesting and waste from milling operations will augment the flow of biomass resources that are potentially available for energy production. There is some overlap between forest materials that might be taken under a commercial harvest operation and forest materials that might be taken for fire threat reduction (Figure 3). This overlap has been estimated in this report to be about 53,000 BDT/y, and is removed from the estimates of harvest potential presented in Tables 15 and 16. The merchantable and non-merchantable components of annual harvest are derived from a five-year average of county timber harvest levels reported by the State Board of Equalization (BOE) in tax years 1999 through 2003. Selecting this period provides a reasonable harvest level for estimating the amount of biomass potentially available from these sources. BOE reports volume in net MBF (thousand board feet in Scribner short-log scale) by county and public/private ownership. The conversion of MBF to BDT/y is based on the ratio of 2.38 million BDT of residue estimated by log consumption to 1,663 MMBF (Scribner scale) in 2003 (Yang and Jenkins, unpublished draft). The amount of slash residue from harvest is estimated by applying the average proportion of non-merchantable biomass to the merchantable component. This proportion is developed from forest inventories. To estimate the amount of slash potentially available from annual harvests this ratio is developed from only softwoods with 10 inches or greater DBH.

3.5 Rotation Calculations and Annualization of Biomass Potentials

The calculation of an annualized yield stream for Gross and Technical biomass potential conceptually requires the calculation of a forest stand "rotation." In forestry terms, rotation is the amount of time a forested stand is allowed to grow before being subjected to an even-aged harvest, where all the trees are removed, and the stand is then regenerated. Selection of rotation length involves biophysical factors such as site productivity and management goals such as economic return.

To estimate annualized yield numbers for Gross and Technical biomass potential, separate rotation lengths and stand treatments are posited for private and U.S. Forest Service lands: 70 years on privately-owned lands, with two thinning entries, and 100 years on U.S. Forest Service lands, with one thinning entry. These values represent the regulated yield over time reflective of intermediate thinning treatments plus removing all biomass in one final harvest. For purposes of this analysis, thinning treatments for stand improvement and fire threat reduction are assumed to be the same type of entry as is presented in the Fire Threat Treatment scenario. Table 2 identifies the percent of total tree biomass taken during intermediate thinning operations for public and private lands.

These are reasonable assumptions for landowners that actively mange forests for fiber; frequently, one or more thinning entries would be used to reduce inter-tree competition (hence remove growth on residual trees) and potentially augment revenues. In a general way, they also seem reflective of the wide variety of forest sites, fire history and other natural processes, past harvesting, current growing stock and management goals found in California. Further, timberland statistics show that nearly 78% of the stands in the state are even-aged. However, national forests are not evaluated according to even or un-even-aged classification and are arbitrarily classified as even-aged. (FRAP, 2003g)

It is highly unlikely that national forests in California will use even-aged harvest routines in the future on substantial areas; however, the construct of a 100-year rotation with one thinning entry is a valid method of estimating annual yields under a sustained management regime where fire threat reduction and forest health improvement are objectives in perpetuity. In contrast, the forest industry on the average owns more productive forestland and manages it more intensively. Even-aged management is often practiced and could well increase in future years (FRAP, 2003g). Rotation lengths vary, but 70 years arguably is a good approximation of current and anticipated practice.

Current management and harvesting on private lands appears sustainable. A method used to evaluate sustainable forest management is the comparison of periodic growth versus periodic harvest as described in FIA statistics. FIA information provides estimates of the total growing stock volume since 1984 and measures changes due to growth, mortality, and harvest removal since 1994. A ratio of harvest divided by net growth summarizes this information. The measurement is developed by dividing harvests by total growth in millions of cubic feet (minus total mortality) during the period for softwood and hardwood forest types. A percentage of 100 indicates that net growth equaled harvest for the period. Over the period of 1984 to 1994, harvest volume was 64 percent of growth on private timberlands for all FIA resource areas (FRAP, 2003g). This is consistent with estimates made later in the report that indicate current harvests as a percentage of Technical potential are near 50% of annualized Technical potential.

3.6 Energy and Capacity Calculations from Biomass

Estimates of gross and technical energy and electric power generation potential from forest and shrub biomass for 2005, 2007, 2010, and 2017 are developed to provide input data to economic models developed for the CEC as part of a statewide assessment for renewable energy systems. Results for these calculations broken out by county are presented in Appendix B: Tables 1 – 4.

The energy (total heating value) from forest and shrub biomass in a given year (MW/y) is obtained for gross, technical, fire technical treatment areas and harvest from the dry mass (BDT/y), constant volume high heating value (Btu/lb dry basis), and overall net generation efficiency:

$$\mathrm{E}_{\mathrm{i,j}} = 5.861 \times 10^{-4} \left[q_{i,j} Q_i \right] \times \eta_{\mathrm{i,j}}$$

where

$$q_{i,j} = \text{dry mass of biomass type } i \text{ projected in year } j \text{ (BDT/y)}$$
$$Q_{i,j} = \text{const.vol.higher heating values of biomass type } i \text{ in year } j \text{ (BTU/lb dry basis)}$$
$$\eta_{i,j} = \text{overall net generation efficiency for biomass type } i \text{ in year } j$$

Higher heating values are show in table 4.

Table 3. Higher heating values (Btu/lb dry basis) of forest and shrub biomass

Biomass Category	Higher Heating Value (Btu/lb dry basis)
Forest Thinnings and Slash	9027
Shrub	8000
Mill Residue	8597

The electric power generation capacities in a given year are calculated from energy (MWh/y), overall net generation efficiency, a power plant capacity factor, and the number 8760 (the number of hours in the year):

$$M_{i,j} = \left[\frac{E_{i,j}\eta_{i,j}}{8760 h_{i,j}} \right]$$

where

$M_{i,j}$ = power generation capacity from biomass type i year j (MWe)

$E_{i,j}$ = annual energy (total heating value) in biomass type i in year j (BDT/y)

$h_{i,j}$ = power plant capacity factor for biomass type i in year j (BDT/y)

$\eta_{i,j}$ = overall net generation efficiency for biomass type i in year j

The power plant capacity factor defines the fraction of rated power capacity for a system achieved over the year. The capacity factor is 85% for all years.

Average net generation efficiencies for thermal conversion are varied by year (Table 4). The efficiency was set at 20% through 2007 and then increased through 2017 under the assumption of improved technology (e.g., continued efficiency upgrading for existing facilities, additions of higher efficiency technologies such as integrated gasification combined cycles).

Table 4. Net conversion efficiencies for years modeled into the future.

Year	Net conversion efficiency (%)
2005	20
2007	20
2010	25
2017	30

4.0 RESULTS

4.1 Total Standing Inventory and Annualized Potentials

We estimate that California currently has a Gross total standing inventory of 1,842 million BDT in all forestry biomass categories, where 730 million BDT is from private lands, 1,093 million BDT from federal lands, and 0.019 million BDT from state and local lands (Table 5). Broken out by material category, gross standing inventories in forest biomass total 1,719 million BDT, of which 1,059 million BDT is from merchantable material and 660 million BDT is non-merchantable materials, and the remaining 123 million BDT is from shrub material (Table 5). A similar data summary, broken out by county, can be found in Appendix A: Table 1.

Table 5. Estimated standing inventory of merchantable and non-merchantable Gross, Technical, and Non-Technical potentials for forest and shrub biomass, by ownership, statewide (million BDT).

	Forestry biomass gross										
	Forest gross							Shrub gross			
	Merchantable*			Non-merchantable**							
Owner	Tech	Non-tech	Potential	Tech	Non-tech	Potential	Potential	Tech	Non-tech	Potential	Potential
Private	228	166	394	169	128	297	691	24	15	39	730
Federal	329	328	657	176	182	358	1,014	36	42	79	1,093
State and local	4	4	8	3	3	6	14	1	4	5	19
Total	561	498	1,059	348	312	660	1,719	62	61	123	1,842

*includes saw logs and mill waste
** includes slash and thinnings

Estimates of Gross annual biomass are summarized in Table 6. We estimate that gross inventory represents a total potential of 39.8 million BDT/y from all material sources, where 19 million BDT are from merchantable forest products, 16 million BDT are from forest non-merchantable material, and 5 million BDT are from shrub biomass. Technical potential, expressed as a percentage of Gross is roughly similar for all categories: merchantable forest materials (54%), non-merchantable forest materials (53%), and shrub materials (52%) (Table 6). A similar data summary, broken out by county, can be found in Appendix A: Table 2.

Table 6. Annual merchantable and non-merchantable Gross, Technical and Non-Technical potentials for forest and shrub biomass, by ownership (thousand BDT/y).

	Forestry biomass gross										
	Forest gross							Shrub gross			
	Merchantable*			Non-merchantable**							
Owner	Tech	Non-tech	Potential	Tech	Non-tech	Potential	Potential	Tech	Non-tech	Potential	Potential
Private	6,323	4,812	11,135	5,870	4,706	10,576	21,711	1,211	743	1,954	23,665
Federal	3,940	3,907	7,847	2,386	2,473	4,858	12,706	1,296	1,437	2,733	15,439
State and local	113	103	216	102	94	196	411	72	180	251	663
Total	10,376	8,821	19,198	8,357	7,273	15,630	34,828	2,580	2,359	4,939	39,767

*includes saw logs and mill waste
** includes slash and thinnings

The Gross standing inventory potential associated with the non-merchantable fraction is broken down in Table 7. Amongst all ownerships, gross potential amounts to 1.37 billion BDT, 228,701 MWe capacity and a total of 1.7 billion MWh. A similar data summary, broken out by county, can be found in Appendix A: Table 3.

Table 7. Total Non-Merchantable (including mill waste and slash/thinnings) Gross potential for forest and shrub biomass (BDT), power generation capacity (MWe), and energy (MWh), by ownership, statewide).

Energy factor	Owner	Non-merchantable forestry biomass gross				
		Forest gross			Shrub gross potential	Potential
		Slash and thinnings	Mill waste	Potential		
BDT	Private	296,887,087	165,320,450	462,207,537	39,079,936	501,287,473
	Federal	357,515,885	375,166,403	732,682,288	78,575,145	811,257,433
	State and local	5,754,050	4,004,771	9,758,821	5,028,127	14,786,948
	Total	660,157,022	544,491,623	1,204,648,645	122,683,209	1,327,331,854
MWe	Private	52,739	27,969	80,708	6,152	86,860
	Federal	63,509	63,471	126,980	12,370	139,350
	State and local	1,022	678	1,700	792	2,491
	Total	117,270	92,118	209,388	19,313	228,701
MWh	Private	392,746,771	208,250,108	600,996,878	45,814,425	646,811,303
	Federal	472,951,554	472,587,899	945,539,453	92,115,685	1,037,655,137
	State and local	7,611,933	5,044,711	12,656,644	5,894,605	18,551,249
	Total	873,310,258	685,882,717	1,559,192,975	143,824,714	1,703,017,689

The same non-merchantable biomass, power capacity, and energy estimates are summarized based on modeled annual potentials in Table 8. Total annual biomass is estimated at 26.7 million BDT/y, power capacity at 4,602 MWe, and energy at 34 million MWh/y. As is evident throughout the analysis, the majority of forest biomass potential comes from private lands, largely due to the more rigorous model used to emulate annualization. Shrub potentials are slightly higher on Federal lands. A similar data summary, broken out by county, can be found in Appendix A: Table 4.

Table 8. Annual non-merchantable Gross potential for forest and shrub biomass (including mill waste and slash/thinnings), expressed as BDT/y, power generation capacity (MWe), and energy (MWh/y), by ownership, statewide.

Energy factor	Owner	Non-merchantable forestry biomass gross					
		Forest gross				Shrub gross potential	Potential
		Slash	Thinnings	Mill waste	Potential		
BDT/y	Private	4,234,332	6,342,057	2,355,864	12,932,253	1,953,997	14,886,250
	Federal	3,656,251	1,202,081	3,783,308	8,641,641	2,733,403	11,375,044
	State and local	81,860	113,832	56,859	252,551	251,406	503,958
	Total	7,972,444	7,657,971	6,196,031	21,826,445	4,938,806	26,765,251
MWe	Private	573	901	319	1,793	246	2,039
	Federal	495	171	512	1,178	344	1,522
	State and local	11	16	8	35	32	67
	Total	1,079	1,088	839	3,006	622	3,628
MWh/y	Private	4,267,828	6,711,838	2,374,500	13,354,166	1,832,577	15,186,743
	Federal	3,685,174	1,272,170	3,813,236	8,770,581	2,563,551	11,334,132
	State and local	82,508	120,469	57,309	260,286	235,784	496,070
	Total	8,035,510	8,104,477	6,245,045	22,385,032	4,631,912	27,016,945

Non-merchantable Technical biomass, capacity, and energy are summarized in Table 9. A total of 637 million BDT is found in Technically available forest materials, which translates to 110,671 MWe capacity, and roughly 824 million MWh in energy. Shrub materials offer much lower biomass—62 million BDT—and associated capacity (9,769 MWe) and energy (73 million MWh). A similar data summary, broken out by county, can be found in Appendix A: Table 5.

Table 9. Total non-merchantable (including mill waste and slash/thinnings) Technical potential for forest and shrub biomass (BDT), power generation capacity (MWe), and energy (MWh/y), by ownership, statewide.

Energy factor	Owner	Forestry biomass tech				
		Forest tech			Shrub tech potential	Potential
		Slash and thinnings	Mill waste	Potential		
BDT	Private	168,945,974	97,691,065	266,637,039	24,229,148	290,866,188
	Federal	175,691,616	189,201,644	364,893,260	36,391,006	401,284,266
	State and local	3,140,090	2,098,117	5,238,207	1,438,098	6,676,305
	Total	347,777,680	288,990,826	636,768,507	62,058,252	698,826,759
MWe	Private	30,012	16,527	46,539	3,814	50,353
	Federal	31,210	32,009	63,219	5,729	68,948
	State and local	558	355	913	226	1,139
	Total	61,779	48,892	110,671	9,769	120,440
MWh	Private	223,495,695	123,059,034	346,554,729	28,404,460	374,959,189
	Federal	232,419,387	238,332,662	470,752,049	42,662,122	513,414,171
	State and local	4,153,971	2,642,947	6,796,918	1,685,920	8,482,837
	Total	460,069,053	364,034,642	824,103,695	72,752,502	896,856,197

When expressed as annual potentials, the non-merchantable Technical pool of biomass yields a grand total of 14.2 million BDT/y, where roughly 82% (11.7 million BDT) comes from forest biomass, and roughly 18% (2.6 million BDT) comes from shrub materials (Table 10). Annual power capacity and energy follow similar trends, with forest totals of 2,048 MWe and 15 million MWh/y, compared to shrub potentials of 406 MWe and 3 million MWh/y. A similar data summary, broken out by county, can be found in Appendix A: Table 6.

Table 10. Annual non-merchantable (including mill waste and slash/thinnings) Technical potential for forest and shrub biomass (BDT/y), power generation capacity (MWe), and energy (MWh/y), by ownership, statewide.

Energy factor	Owner	Forestry biomass tech					
		Forest tech				Shrub tech potential	Potential
		Slash	Thinnings	Mill waste	Potential		
BDT/y	Private	2,409,802	3,460,198	1,391,611	7,261,612	1,211,457	8,473,069
	Federal	1,797,188	588,500	1,907,786	4,293,474	1,296,354	5,589,829
	State and local	44,669	57,108	29,771	131,548	71,905	203,453
	Total	4,251,659	4,105,807	3,329,168	11,686,634	2,579,716	14,266,351
MWe	Private	342	492	188	1,023	153	1,175
	Federal	255	84	258	597	163	761
	State and local	6	8	4	18	9	28
	Total	604	583	451	1,638	325	1,963
MWh/y	Private	2,550,309	3,661,949	1,402,620	7,614,877	1,136,178	8,751,056
	Federal	1,901,975	622,814	1,922,878	4,447,666	1,215,800	5,663,466
	State and local	47,273	60,438	30,006	137,718	67,437	205,154
	Total	4,499,557	4,345,201	3,355,504	12,200,261	2,419,415	14,619,676

We estimate that there is a standing inventory total of 182 million BDT forestry biomass in the FTTA, where 93 million is from merchantable forest material, where 78 million non-merchantable forest material and 11 million BDT from shrub material. The WUI non-WUI breakdown shows 66 million BDT in the WUI and 104 million BDT is in the non-WUI area (Table 11). Total biomass across ownerships has an even breakdown between private and federal (91 vs 89 million BDT) with about 1% of the total (2 million BDT) coming from the state publicly owned and local group. A similar data summary, broken out by county, can be found in Appendix A: Table 7.

Table 11. Estimated standing inventory of merchantable and non-merchantable forest and shrub biomass potential (million BDT) from the Fire Threat Treatment Area (FTTA), including WUI and non-WUI components, by ownership, statewide.

	Forestry biomass fire threat treatment area										
	Forest fire threat treatment area									Shrub FTTA potential	
	Merchantable FTTA*			Non-merchantable FTTA**							
Owner	WUI	Non-WUI	Potential	WUI	Non-WUI	Potential	WUI	Non-WUI	Potential		Potential
Private	18	21	39	22	23	45	40	44	84	7	91
Federal	17	36	53	8	23	32	25	60	85	4	89
State and local	<.5	<.5	1	<.5	<.5	1	1	1	1	<.5	2
Total	36	57	93	30	47	78	66	104	170	11	182

*includes saw logs and mill waste
** includes slash and thinnings

Total annual biomass potentials modeled for the FTTA, including the merchantable fractions, indicate a total of 5.2 million BDT/yr of forestry biomass across all material types, where 2.0 million BDT are in the WUI (Table 12). Slightly less than half of the total (46%) is from merchantable forest material. As elsewhere, the annualized yields are dominated by private forest material sources (64%). A similar data summary, broken out by county, can be found in Appendix A: Table 8.

Table 12 – Annual merchantable and non-merchantable forest and shrub biomass potential (thousand BDT/y) from the Fire Threat Treatment Area (FTTA), including WUI and non-WUI components, by ownership, statewide.

	Forestry biomass fire threat treatment area										
	Forest fire threat treatment area									Shrub FTTA potential	
	Merchantable FTTA*			Non-merchantable FTTA**							
Owner	WUI	Non-WUI	Potential	WUI	Non-WUI	Potential	WUI	Non-WUI	Potential		Potential
Private	735	821	1,557	860	933	1,793	1,595	1,754	3,349	346	3,695
Federal	270	570	840	149	385	533	418	955	1,373	101	1,475
State and local	14	12	26	17	14	30	31	26	56	13	69
Total	1,019	1,404	2,423	1,025	1,331	2,357	2,044	2,735	4,779	459	5,239

*includes saw logs and mill waste
** includes slash and thinnings

Non-merchantable biomass potential in the FTTA totals 103 million BDT, with associated power capacity of 18,022 MWe and energy of 134 million MWh (Table 13). 90% of the total comes from forest materials, of which slash/thinnings are the dominant component. The majority of non-merchantable biomass (62%) is in non-WUI. A similar data summary, broken out by county, can be found in Appendix A: Table 9.

Table 13. Total non-merchantable (including mill waste and slash/thinnings) biomass potential from the Fire Threat Treatment Area (FTTA), for forest and shrub biomass (BDT), power generation capacity (MWe), and energy (MWh/y), by ownership, statewide.

Energy factor	Owner	Forestry biomass fire threat treatment area										
		Forest fire threat treatment area									Shrub FTTA potential	Potential
		Mill waste			Slash and thinnings							
		WUI	Non-WUI	Potential	WUI	Non-WUI	Potential	WUI	Non-WUI	Potential		
BDT/y	Private	1,768,070	2,558,907	4,326,977	21,545,314	23,375,821	44,921,135	23,313,384	25,934,728	49,248,112	6,910,688	56,158,800
	Federal	2,282,664	7,712,658	9,995,321	8,493,330	23,458,145	31,951,475	10,775,993	31,170,802	41,946,796	4,212,231	46,159,027
	State and local	45,299	53,328	98,766	422,458	341,720	764,178	467,756	395,048	862,944	251,709	1,114,653
	Total	4,096,032	10,324,893	14,421,065	30,461,102	47,175,685	77,636,787	34,557,134	57,500,578	92,057,852	11,374,628	103,432,481
MWe	Private	299	433	732	3,827	4,152	7,980	4,126	4,585	8,712	1,088	9,800
	Federal	386	1,305	1,691	1,509	4,167	5,676	1,895	M	7,367	663	8,030
	State and local	8	9	17	75	61	136	83	70	152	40	192
	Total	693	1,747	2,440	5,411	8,380	13,791	6,104	10,127	16,231	1,791	18,022
MWh/y	Private	2,227,195	3,223,392	5,450,587	28,501,922	30,923,467	59,425,389	30,729,117	34,146,860	64,875,976	8,101,579	72,977,555
	Federal	2,875,415	9,715,445	12,590,860	11,235,679	31,032,372	42,268,051	14,111,094	40,747,817	54,858,911	4,938,108	59,797,019
	State and local	57,062	67,176	124,414	558,862	452,055	1,010,917	615,924	519,232	1,135,331	295,085	1,430,416
	Total	5,159,671	13,006,014	18,165,861	40,296,463	62,407,895	102,704,358	45,456,134	75,413,909	120,870,219	13,334,773	134,204,991

Annual biomass from non-merchantable materials and associated energy potentials from the FTTA indicate a yearly total of 3.1 million BDT, 547 MWe capacity and 4 million MWh/y (Table 14). Forest biomass dominates the source in FTTA, amounting to 2.7 million BDT, or 87% of the total. As previously noted in the table summarizing annual FTTA potentials with non-merchantable material included, here we see the forest fraction dominated by the non-WUI lands, although somewhat augmented by the inclusion of the 459,461 BDT from brush, which due to the model all comes from WUI. A similar data summary, broken out by county, can be found in Appendix A: Table 10.

Table 14. Annual non-merchantable (including mill waste and slash/thinnings) biomass potential from the Fire Threat Treatment Area (FTTA), for forest and shrub biomass (BDT/y), power generation capacity (MWe), and energy (MWh/y), by ownership, statewide.

Energy factor	Owner	Forestry biomass fire threat treatment area										
		Forest fire threat treatment area									Shrub FTTA potential	Potential
		Mill waste			Slash and thinnings							
		WUI	Non-WUI	Potential	WUI	Non-WUI	Potential	WUI	Non-WUI	Potential		
BDT/y	Private	70,219	101,647	171,866	859,908	932,844	1,792,752	930,127	1,034,492	1,964,618	345,534	2,310,153
	Federal	35,180	117,630	152,810	148,558	384,815	533,374	183,738	502,446	686,184	101,341	787,525
	State and local	1,787	2,107	3,894	16,806	13,585	30,391	18,593	15,692	34,285	12,585	46,870
	Total	107,186	221,384	328,570	1,025,272	1,331,245	2,356,517	1,132,458	1,552,629	2,685,087	459,461	3,144,548
MWe	Private	12	17	29	153	166	318	165	183	348	54	402
	Federal	6	20	26	26	68	95	32	88	121	16	137
	State and local	0	0	1	3	2	5	3	3	6	2	8
	Total	18	37	56	182	236	419	200	274	474	72	547
MWh/y	Private	88,453	128,043	216,496	1,137,557	1,234,043	2,371,601	1,226,010	1,362,086	2,588,096	405,079	2,993,175
	Federal	44,316	148,176	192,492	196,525	509,066	705,591	240,841	657,241	898,082	118,805	1,016,887
	State and local	2,251	2,654	4,905	22,233	17,971	40,204	24,484	20,625	45,109	14,754	59,863
	Total	135,020	278,872	413,892	1,356,315	1,761,080	3,117,395	1,491,335	2,039,953	3,531,287	538,638	4,069,925

There is some overlap between forest materials that might be taken under a commercial harvest operation and forest materials that might be taken for fire threat reduction scenarios. This overlap has been estimated in this report to be about 53,000 BDT/y (about 26,000 BDT/y merchantable timber and 27,000 BDT/y of Non-merchantable material),

and is removed from the estimates of harvest potential presented in Tables 15 and 16. Overlap adjusted summaries of merchantable and non-merchantable biomass potentials reflected by an annual average from harvest totals over the period 1999-2003 show harvest producing a total of 5.6 million BDT annually, where 4.1 million are merchantable materials (Table 15). The vast majority of biomass from harvest operations (86%) is coming from private lands. Only 1.4 million BDT of material associated with harvest is non-merchantable, and is potentially available for energy production. A similar data summary, broken out by county, can be found in Appendix A: Table 11.

Table 15. Annual merchantable and non-merchantable forest biomass potential (BDT/y) from Harvest, by ownership, statewide.

Owner	Forest biomass annual harvest		
	Merchantable*	Non-merchantable**	Potential
Private	3,534,889	1,261,099	4,795,988
Federal	549,903	198,418	748,321
State_local	36,578	12,900	49,479
Total	4,121,370	1,472,417	5,593,788

*includes saw logs and mill waste
** includes slash and thinnings

The annual non-merchantable biomass associated with harvest indicates a total of 4.1 million BDT, and represents a potential of 700 MWe capacity, and 5.2 million MWh/y energy. Roughly one-third (36%) comes from slash/thinnings and two-thirds (64%) from mill. The majority of this biomass, 3.5 million BDT, comes off private lands. A similar data summary, broken out by county, can be found in Appendix A: Table 12.

Table 16. Annual non-merchantable forest biomass potential from Harvest, expressed as BDT/y, power generation capacity (MWe), and energy (MWh/y), by ownership, statewide.

Energy factor	Owner	Forest biomass annual harvest		
		Slash and thinnngs	Mill waste	Potential
BDT/y	Private	1,261,099	2,217,589	3,478,688
	Federal	198,418	351,957	550,375
	State_local	12,900	23,969	36,869
	Total	1,472,417	2,593,515	4,065,932
MWe	Private	224.02	375.17	599
	Federal	35.25	59.54	95
	State_local	2.29	4.06	6
	Total	261.56	438.77	700
MWh/y	Private	1,668,286	2,793,442	4,461,728
	Federal	262,484	443,351	705,835
	State_local	17,065	30,193	47,258
	Total	1,947,835	3,266,987	5,214,822

5.0 DISCUSSION

5.1 Limitations Associated with Inventory- and Fuel Model-based estimates of biomass

The use of forest inventory data for the purposes of estimating biomass potentials raises a number of issues that bear on the interpretation of the numbers. For one, the inventory data itself comes from samples that are more than a decade old (1991-1994) in the case of private lands, and from a slightly more current period for the national forests (1996-2000). Although all estimates are based on less-than-current data, PNW and CDF forest measurement experts agree that these data represent a valid "snapshot" in time and that without precise knowledge of harvest intensity or location, estimating net growth over time introduces a degree of uncertainty and adds little to the analysis. Conclusions regarding biomass potentials at any particular location should take into account local forest structure, management practices, land-use impacts, and many other factors.

The forest biomass volumes derived from the inventory are the basis for estimates of standing gross and technical forest biomass potential, and availability can be construed both in the context of a single year or over some fixed interval of future years. The development of annualized yield streams of biomass reflect very general assumptions about how forests are likely to be managed in the future given an understanding of how forests grow, respond to intermediate thinning harvests, and are regenerated. When considering how these potentials can help to solve emerging energy issues, the rate of removal can be varied according to policy alternatives ranging from "business as usual" to aggressive action.

Biomass potentials in the FTTA are focused on a particular subcategory of vegetation and landscape description. The model includes only basic intermediate thinning prescriptions designed to improve forest heath and reduce Fire Threat. There is no regeneration harvest included in the yield stream. These "fire mitigation, thin-from-below" prescriptions are both conservative with respect to biomass yields, and entirely consistent with current forest policy on Forest Service lands (USFS 2004d, Klaus Barber, pers. comm.) and on private timberlands (CDF 2004) to deal with the well recognized fire issue in California's forests.

In the FTTA, the identification of WUI emphasizes the public benefit opportunity for fire mitigation activities that yield biomass suitable for energy production. This emphasis is consistent with existing public policies that call for half of all forest service vegetation treatments to be targeted in the WUI. Moreover, fire hazard harvest exemptions to timber harvest plans are targeted to WUI. Biomass potentials in both the WUI and non WUI portions of the FTTA provide useful information for exploring significant public benefits from biomass harvest that would otherwise be a marginal economic activity.

There are other practical issues associated with actual biomass utilization practices that bear on the interpretation of biomass yields. A realistic new biomass stream associated with forest management would not include mill waste materials that are already being redirected back into the forest product manufacturing system (plant energy production, secondary products, etc.). Thus slash and thinnings represent the likely new material available for energy. These numbers are emphasized both in the liberal interpretation of technical potential and the conservative estimate for FTTA and new opportunities for biomass capture from ongoing harvest.

With respect to biomass estimates from shrublands, the accuracy of broad fuel model-based derivations of biomass are somewhat more uncertain than forest biomass estimated

from site specific sample plots. While some research on standing total biomass from destructive sampling by PSW indicates that these numbers are conservative for many chaparral systems, the relatively high fire-dynamics in these vegetation types add variability to our estimates. Moreover, the practical economic considerations outlined above for forest materials are even more difficult, given the relatively low yields and high costs associated with utilizing shrub materials. The nature of the fire problem in shrublands is also typically more acute due to higher fire threat in shrublands and chaparral. Our restriction of treatment of shrublands in FTTA to WUI only reflects these realities in a way that tries to offset the difficulties associated with shrub biomass with very high benefits.

5.2 Tiering of Biomass Opportunities Associated with Technical, FTTA, and WUI

The tiered breakdown of standing non-merchantable biomass availability (BDT/ac) going from Gross to Technical to FTTA to FTTA-WUI is shown in the four-panel Figure 9a-d. Similar trends, albeit somewhat modified based on different models for ownership would follow for annual biomass. As is evident by the thinned out picture represented by the Technical plot (9b), much of what is available as Gross goes away once administrative and technical limitations are imposed. The highest Technical potentials are in the NW portion of the state, with high levels throughout the Northern Coast Range and Sierra Nevada, where values range from approximately 20-112 BDT/ac. These are generally consistent with numbers coming from modeled regulated forest structure based on typical even-aged management regimes, site class, and published yield values (FRAP, 2005d). Biomass levels in the FTTA and the WUI portion of the FTTA (Figs 9c and 9d, respectively) indicate progressively smaller amounts of available biomass.

A similar tiering of potential is presented in Figure 10a-d, where annual power capacity from the suite of biomass opportunity groups are summarized by county. As in the Figure 9, Gross and Technical capacity is highest in the NW and Sierra Nevada. The county MWe for FTTA shows a similar trend, but some other portions of the state (e.g., Monterey and San Diego counties) have moderately high capacity from widespread FTTA (Figure 10c). Finally, the influence of current forest practice on the harvest potential, where the highest harvest levels come from the NW corner of the state and the northern Sierra Nevada (Figure 10d).

Figure 9. Standing inventory of non-merchantable biomass (BDT/ac), Gross potential (a); Technical potential (b); Fire Threat Treatment Area (FFTA) (c); and Wildland-Urban Interface (d).

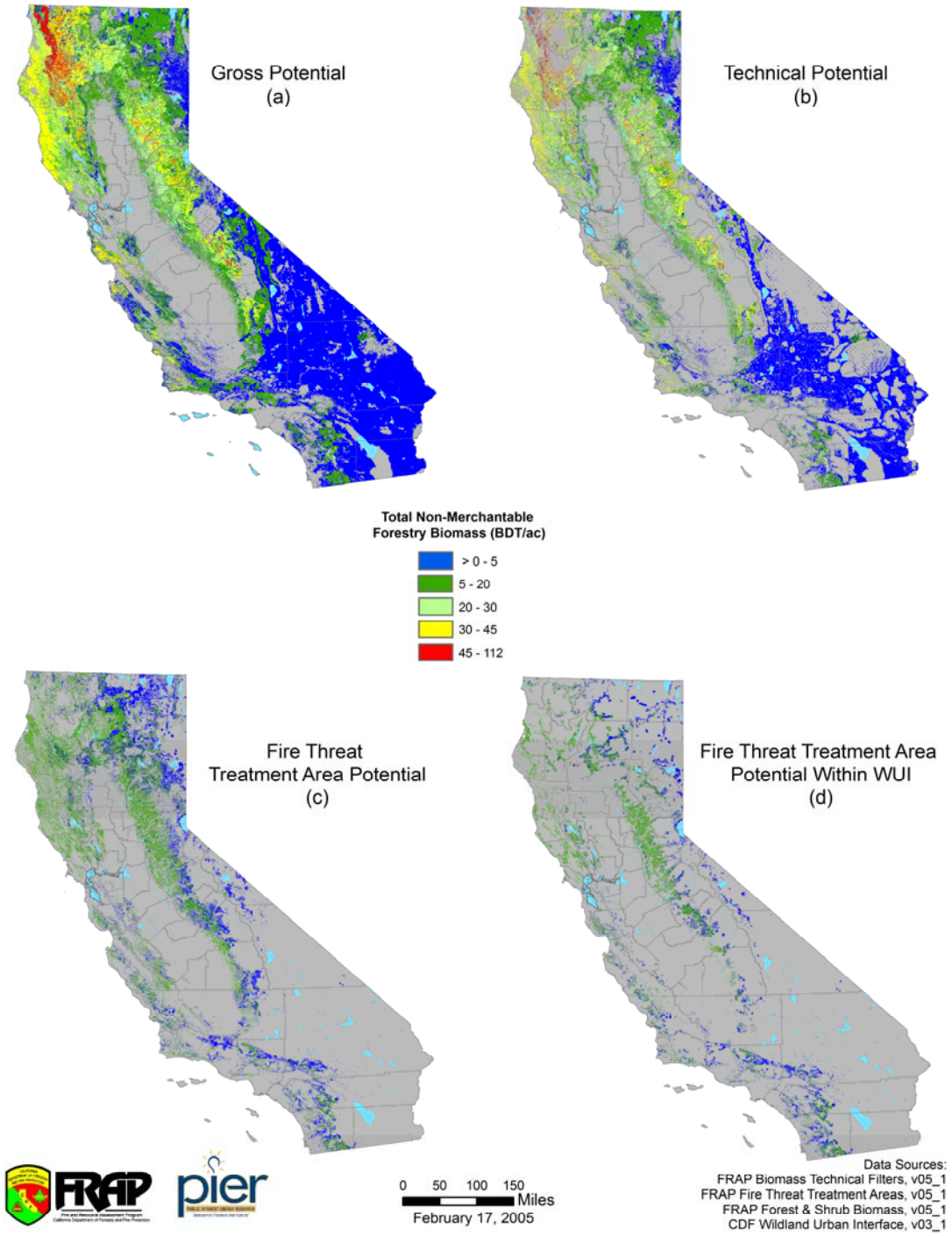
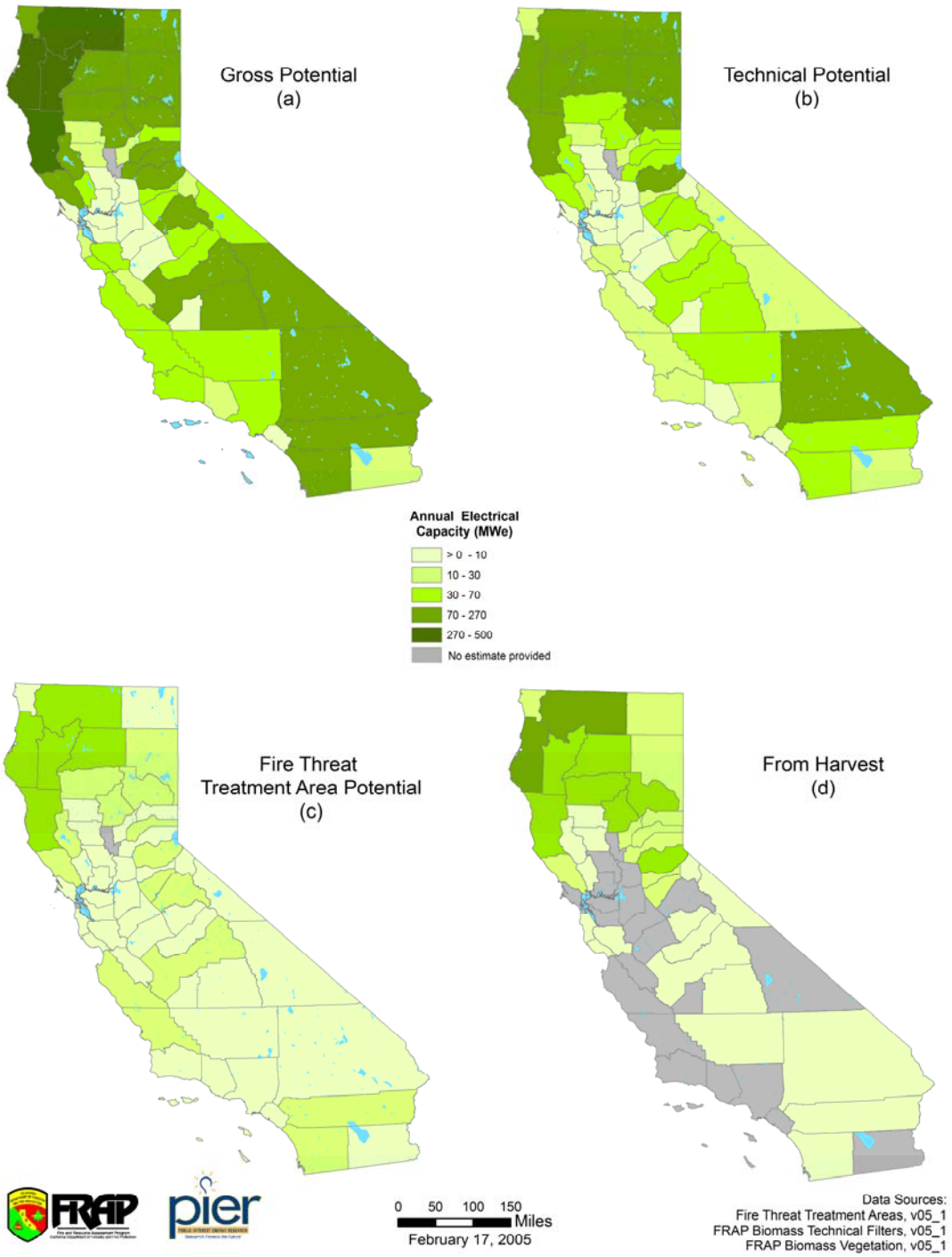


Figure 10. Annual Electrical Capacity (MWe) from forestry biomass, by county for Gross potential (a); Technical potential (b); Fire Threat Treatment Area (FTTA0 (c); and Harvest (d).



Another way of looking at the spatial arrangement of biomass opportunities coming from FTTA biomass potential uses the GIS to develop a "moving window" summary to explore how much energy potential exists within a given area. This type of neighborhood analysis was calculated on the FTTA annual biomass data grid using a neighborhood search distance of 25 miles (where the value in any given cell represents the sum of all cell values within a 25 mile radius of that cell). This type of analysis is particularly useful for identifying locations for biomass production plants where there is sufficient biomass close by to serve the facility economically (Figure 11). As is evident by the yellow and red areas, the FTTA model provided greater than 100,000 BDT/y within the 25 mile search window over much of the NW and Northern Sierra Nevada. In particular, areas of Humboldt, Shasta, Butte, Nevada, Placer, and Eldorado counties have very high concentrations of biomass available from the FTTA, with some areas exceeding 140,000 BDT/y across the search window (Figure 11).

The annual Technical biomass potential likely available as a new product for energy is the sum of slash/thinnings from fire treatment strategy, slash/thinnings associated with ongoing harvest activities and biomass from brush treated for fire threat. Concentrating a biomass program on the FTTA to ameliorate significant Fire Threat would see a potential of 4.2 million BDT/y and a power capacity potential of 753 MWe. The majority of these potentials are from private lands, and the source material is mostly FTTA forest materials (55%), followed by harvest slash/thinnings (34%), with the balance being from shrub biomass potential (11%) (Table 17).

Table 17. Annual biomass opportunity as new product source for energy production in FTTA (BDT/y, MWe, MWh/y)

Energy factor	Owner	Forestry biomass fire threat treatment area and harvest area			
		FTTA slash and thinnings	FTTA shrub	Harvest slash and thinnings	Potential
BDT/y	Private	1,792,752	345,534	1,261,099	3,399,386
	Federal	533,374	101,341	198,418	833,133
	State_local	30,391	12,585	12,900	55,877
	Total	2,356,517	459,461	1,472,417	4,288,395
MWe	Private	318	54	224	597
	Federal	95	16	35	146
	State_local	5	2	2	10
	Total	419	72	262	753
MWh/y	Private	2,371,601	405,079	1,668,286	4,444,966
	Federal	705,591	118,805	262,484	1,086,879
	State_local	40,204	14,754	17,065	72,024
	Total	3,117,395	538,638	1,947,835	5,603,869

A spatial exploration of this new product source opportunity is shown by totaling the annual power capacity from the combined FTTA slash, FTTA shrub and annual harvest, by county (Figure 12). Humboldt county has the highest capacity estimated from FTTA, with Siskiyou and Shasta following and numerous other counties ranging from Modoc to San Diego showing annual capacity greater than 10 MWe (Figure 12).

Figure 11. Annual potential biomass (BDT) from Fire Threat Treatment Area (FTTA), based on 25 mile neighborhood

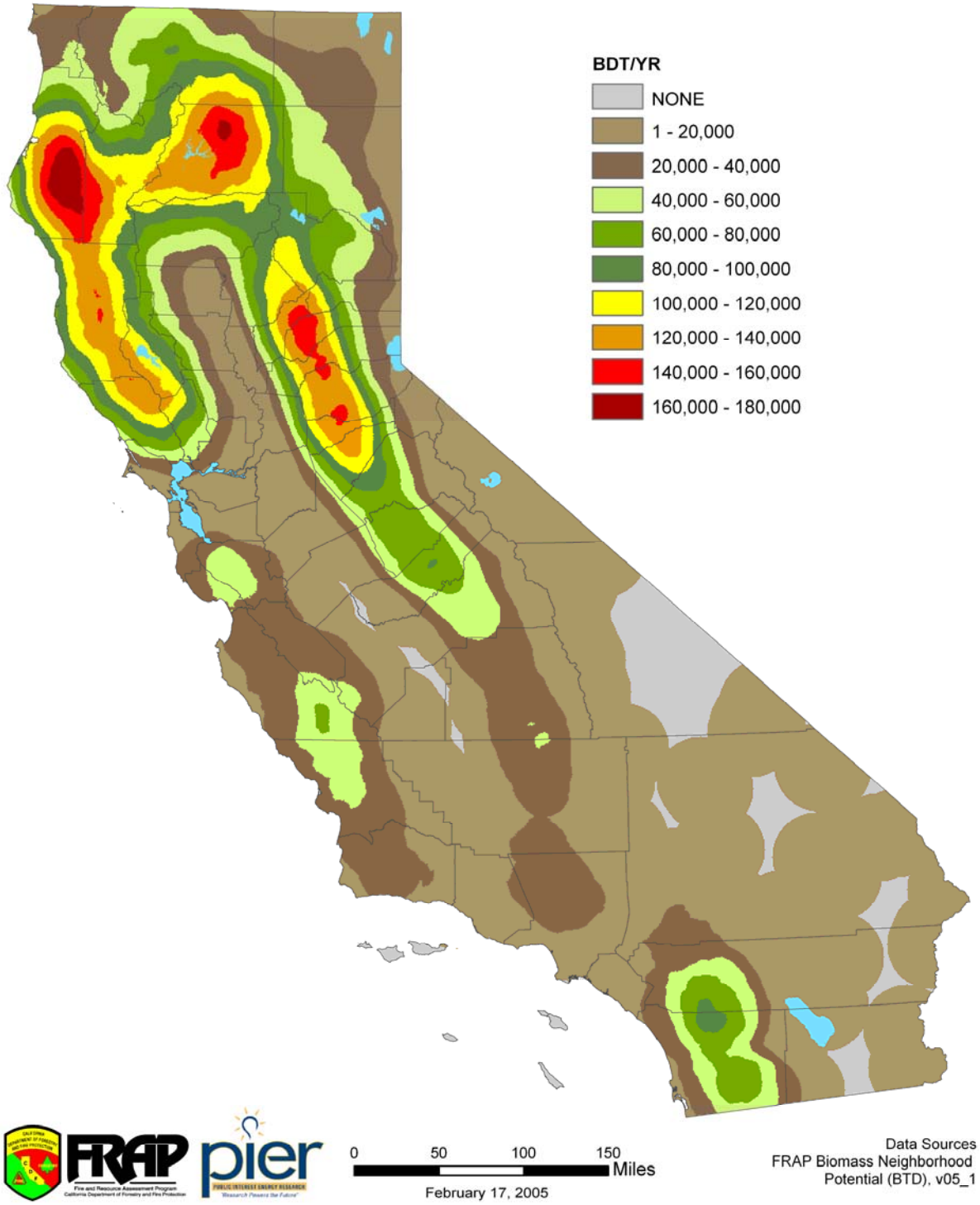


Figure 12. Annual Electrical Capacity (MWe) of slash and thinnings from Fire Threat Treatment Area (FTTA) Shrub Biomass and average annual Harvest potentials

5. 3 Fire Threat Reduction in the Wildland-Urban Interface

Elevated fire threat is widespread in California (Figure 6). Approximately 48% of the State's 101 million acres exhibit High, Very High or Extreme Fire Threat. Of that area, 27.6 million acres are in the WUI. According to the Forest and Range 2003 Assessment (FRAP 2003c), communities at risk from elevated fire threat contain 4.9 million residences. The surrounding, sparsely populated areas of the wildland urban interface contain an additional 230,000 housing units for a total of 5.15 million units in the WUI. This total is 884,000 more units than in 1990, translating to an annual growth rate in the WUI of 1.7%, nearly double that of areas outside of the WUI. Another 10,000 housing units in sparsely populated areas outside the WUI also experience an elevated threat of wildland fire (FRAP 2005d). In all, 42% of the State's 12.21 million residences (5.16 million) are currently subject to a fire threat rating of High, Very High or Extreme.

Since 1990, 1,993,000 acres of WUI area have burned (an average of 142,000 acres per year). An analysis of fire history in the WUI indicates an overall fire return interval (rotation) of approximately 194 years. This equates to an annual probability that a given area will burn in any given year of 0.00516 (FRAP 2005). Using this probability of fire, FRAP estimates that 1530 houses per year will be lost at a replacement value of $505,000 per unit[5]. Annual housing-related losses total $772.65 million. Non-structure related impacts total $32.38 million annually and includes losses from timber, watershed rehabilitation costs, and non-timber values such as forage and uncultivated trees. Using a discount rate of 7%, FRAP estimates the present net worth of this $805 million combined annual potential loss to be over $6.7 billion by 2017.

Given this high risk element, this analysis focuses on fuel reduction in the FTTA, and especially in the WUI, a crucial public policy issue. It is possible to characterize opportunities in the WUI as way of prioritizing the potential public benefit that might be realized through fuel treatments that utilize biomass. Using the same new source criteria as outlined above – namely forest potential from slash and thinnings due to fuel treatments in the forest, material from fuel treatments of shrub lands, and estimates of slash/thinnings associated with ongoing harvests – we sum biomass and energy potentials solely within the FTTA-WUI intersection in Table 18.

2 million BDT/yr of forestry biomass are estimated to be available in the WUI, which represents a power capcity of 302 MWe, and an annual energy supply potential of 2.7 million MWh. These data reflect only lands within the WUI, with many of the areas meeting the definition of FTTA, but some of the areas having an annual harvest potential. These areas are consequently significantly limited in extent (See Figure 9d for general idea of extent).

[5] includes costs of structure, landscaping, contents, disruption, dislocation, insurance transactions, uninsured intangibles and other improvements, and fatalities and injuries

Table 18. Annual biomass opportunity as new product source for energy production in WUI (BDT/y, MWe, MWh/y)

Energy factor	Owner	Forestry biomass fire threat treatment area and harvest area (WUI)			
		FTTA slash and thinnings (WUI)	FTTA shrub (WUI)	Harvest slash and thinnings (WUI)	Potential
BDT/y	Private	859,908	345,534	532,854	1,738,297
	Federal	148,558	101,341	63,326	313,226
	State_local	16,806	12,585	6,843	36,235
	Total	1,025,272	459,461	603,024	2,087,758
MWe	Private	153	54	95	302
	Federal	26	16	11	54
	State_local	3	2	1	6
	Total	182	72	107	362
MWh/y	Private	1,137,557	405,079	704,904	2,247,540
	Federal	196,525	118,805	83,773	399,103
	State_local	22,233	14,754	9,053	46,040
	Total	1,356,315	538,638	797,730	2,692,683

6.0 SUMMARY

Forest and shrublands throughout California present significant risks to natural resources, public and private property and public safety. In this paper we show how much forest and shrub biomass potential is present statewide and how these materials are contained in various land classes. These materials are then categorized as a biomass resource in the framework of potential public benefits coming from fuel reduction activities in significant Fire Threat areas. We further narrow the context of biomass opportunities down to the core area identified as where the highest risks to people and property occur – the Wildland-Urban Interface. We believe biomass opportunities on lands posing significant risks from wildfire offer very high potential public benefits, and that when internalized into the economic scenario may drive public policy to develop these resources.

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