March 7, 2019

SPECIFICATION SHEET: BEIS Biogenics 2016beta Platform

Description: Biogenic emissions estimated from the Biogenic Emission Inventory System version 3.61 (BEIS3.61) model for simulating 2016 air quality.

1. EXECUTIVE SUMMARY

Biogenic emissions are generated with the Biogenic Emissions Inventory System (BEIS) model, which is internal to the Sparse Matrix Operating Kernel Emissions (SMOKE) modeling system version 4.6. SMOKE creates emissions in a format that can be input into air quality models. BEIS uses gridded hourly meteorology, gridded land use, emission factors, and a speciation profile to generate hourly biogenic emissions for use in air quality modeling. National and state-level emission summaries for key pollutants are provided.

2. INTRODUCTION

This document details the approach and data sources to be used for developing 2016 biogenic emissions using the BEIS model.

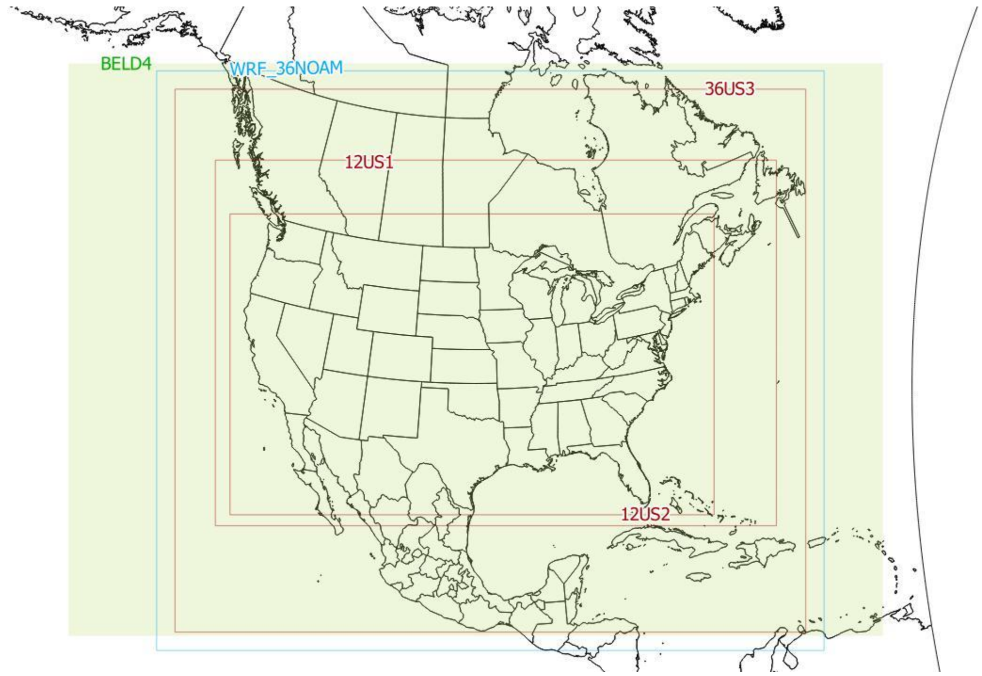
Biogenic emissions can be computed either within CMAQ itself (inline option) or using the Biogenic Emission Inventory System version 3.61 (BEIS3.61) within SMOKE. The BEIS3.61 creates gridded, hourly, model-species emissions from vegetation and soils. It estimates CO, VOC (most notably isoprene, terpene, and sesquiterpene), and NO emissions for the contiguous U.S. and for portions of Mexico and Canada. Even when using the CMAQ inline option, it is still necessary to run the SMOKE program Normbeis, as described in Section 6 of this document.

3. INVENTORY DEVELOPMENT METHODS

Biogenic emissions for the entire year 2016 were developed using the Biogenic Emission Inventory System version 3.61 (BEIS3.61) within SMOKE. The landuse input into BEIS3.61 is the Biogenic Emissions Landuse Dataset (BELD) version 4.1 which is based on an updated version of the USDA-USFS Forest Inventory and Analysis (FIA) vegetation speciation-based data from 2001 to 2014 from the FIA version 5.1.

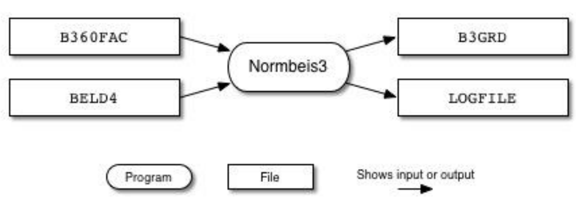
BEIS3.61 has some important updates from BEIS 3.14. These include the incorporation of Version 4.1 of the Biogenic Emissions Landuse Database (BELD4), and the incorporation of a canopy model to estimate leaf-level temperatures (Pouliot and Bash, 2015). BEIS3.61 includes a two-layer canopy model. Layer structure varies with light intensity and solar zenith angle. Both layers of the canopy model include estimates of sunlit and shaded leaf area based on solar zenith angle and light intensity, direct and diffuse solar radiation, and leaf temperature (Bash et al., 2015). The new algorithm requires additional meteorological variables over previous versions of BEIS. The variables output from the Meteorology-Chemistry Interface Processor (MCIP) that are used for BEIS3.61 processing are shown in Table 1. The beta version of the BEIS3 modeling for year 2016 included processing for both a 36km (36US3) and 12km domain (12US1) (see Figure 1). The 12US2 modeling domain can also be supported by taking a subset or window of the 12US1 BEIS3 emissions dataset.

Figure 1. Various EPA modeling domains including 36US3 (36km) and 12US2 (12km).



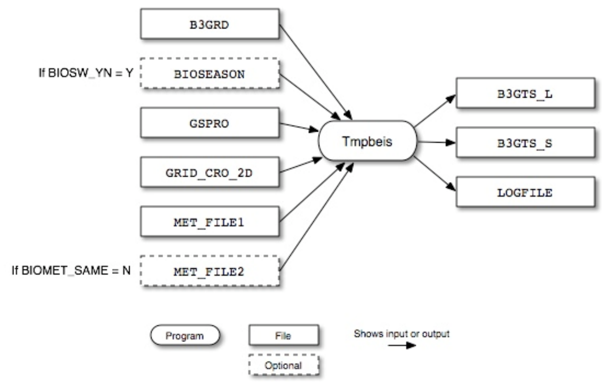
SMOKE-BEIS3 modeling system consists of two programs named: 1) Normbeis3 and 2) Tmpbeis3. Normbeis3 uses emissions factors and BELD4 landuse to compute gridded normalized emissions for chosen model domain (see Figure 2). The emissions factor file (B360FAC) contains leaf-area-indices (LAI), dry leaf biomass, winter biomass factor, indicator of specific leaf weight, and normalized emission fluxes for 35 different species/compounds. The BELD4 file is the gridded landuse for 276 different landuse types. The output gridded domain is the same as the input domain for the land use data. Output emission fluxes (B3GRD) are normalized to 30 °C, and isoprene and methyl-butenol fluxes are also normalized to a photosynthetic active radiation (PAR) of 1000 μmol/m^{2}s.

Figure 2. Normbeis3 data flows



The normalized emissions output from Normbeis3 (B3GRD) are input into Tmpbeis3 along with the MCIP meteorological data, chemical speciation profile to use for desired chemical mechanism, and BIOSEASON file used to indicate how each day in year 2016 should be treated, either as summer or winter. Figure 3 illustrates the data flows for the Tmpbeis3 program. The output from Tmpbeis includes gridded, speciated, hourly emissions both in moles/second (B3GTS_L) and tons/hour (B3GTS_S).

Figure 3. Tmpbeis3 data flow diagram.



Biogenic emissions do not use an emissions inventory and do not have SCCs. The gridded land use data, gridded meteorology, an emissions factor file, and a speciation profile are further described in the next section.

4. Ancillary Data

Gridded land use

The BELD version 4.1 land use is based on an updated version of the USDA-USFS Forest Inventory and Analysis (FIA) vegetation speciation based data from 2001 to 2014 from the FIA version 5.1. Canopy coverage is based on the Landsat satellite National Land Cover Database (NLCD) product from 2011. The FIA includes approximately 250,000 representative plots of species fraction data that are within approximately 75 km of one another in areas identified as forest by the NLCD canopy coverage. The 2011 NLCD provides land cover information with a native data grid spacing of 30 meters. For land areas outside the conterminous United States, 500 meter grid spacing land cover data from the Moderate Resolution Imaging Spectroradiometer (MODIS) is used. BELDv4.1 also incorporates the following:

- 30 meter NASA's Shuttle Radar Topography Mission (SRTM) elevation data (http://www2.jpl.nasa.gov/srtm/) to more accurately define the elevation ranges of the vegetation species than in previous versions; and
- 2011 30 meter USDA Cropland Data Layer (CDL) data (https://www.nass.usda.gov/Research_and_Science/Cropland/Release/).

Land use data from BELDv4.1 is converted to a gridded file for use in SMOKE / BEIS for each modeling domain. BELDv4.1 data is represented as 24 separate files called “tiles”. These tiles can be regridded to standard modeling domains using the Spatial Allocator (https://github.com/CMASCenter/Spatial-Allocator) program.

The BELDv4.1 land use for 2016 beta platform includes two additional updates:

- Land use changes were made for the states of Florida, Texas and Washington to correct an error with the land use fractions which did not sum to 1. This update was also incorporated into 2014NEIv2, and is sometimes referred to as the February 2017 version of BELDv4.1.
- BELDv4.1 land use was found to have insufficient water coverage for inland rivers and lakes. To address this, water data from the MCIP GRIDCRO2D file, which is based on a different land use source (usually NLCD) and has better representation of inland waterways, was merged into the gridded BELD file in place of the original water data (variable name MODIS_0). All other variables' land use percentages were changed linearly so that the sum of all variables would remain 1. This update resulted in more inland water coverage, and therefore, lower biogenic emissions (about 2% decrease nationally on average). This is new for beta platform and is sometimes referred to as the "water fix" version of BELDv4.1.

Meteorology (including BIOSEASON)

Gridded meteorology from MCIP is used by BEIS to estimate biogenic emissions. A list of the MCIP variables required to run BEIS is listed in Table 1. These variables are all available in the METCRO2D file.

Table 1. Hourly Meteorological variables required by BEIS 3.61

Variable	Description
LAI	leaf-area index
PRSFC	surface pressure
Q2	mixing ratio at 2 m
RC	convective precipitation
RGRND	solar rad reaching sfc
RN	nonconvective precipitation
RSTOMI	inverse of bulk stomatal resistance
SLYTP	soil texture type by USDA category
SOIM1	volumetric soil moisture in top cm
SOIT1	soil temperature in top cm
TEMPG	skin temperature at ground
USTAR	cell averaged friction velocity

Variable	Description
RADYNI	inverse of aerodynamic resistance
TEMP2	temperature at 2 m

In addition to reading the MCIP files directly, SMOKE also requires generation of a file called the BIOSEASON file, which is a gridded representation of the growing season. The BIOSEASON file includes a single variable called SEASON, which is set to 1 during the growing season (the time period after the last freeze of spring and before the first freeze of fall) and 0 outside the growing season. This file can be generated with the SMOKE program Metscan.

Metscan reads in annual temperature I/O API meteorology data file (created from either the MET_CRO_2D or MET_CRO_3D files) and determines the first freeze date and last freeze date of a year, by grid cell. It outputs a gridded file with a daily (24-hour) time step that contains a single variable. For each grid cell, that variable has a value of 0 (zero) when the date being modeled indicates that the cell is experiencing winter conditions; otherwise it has a value of 1, indicating summer conditions. The program can be set to run in the Northern Hemisphere or in the Southern Hemisphere (it will not work on global meteorology datasets). In the Northern Hemisphere, the first freeze date in the fall marks the start of winter, and the last freeze date in the spring marks the end of winter; all other days are considered summer days.

The BEIS3 model operates using the assumption of either winter or summer emission factors. There are no spring or fall factors available, which is why Metscan is limited to the choice of summer or winter. The use of the freeze date to determine summer or winter emission factors is based on EPA's recommendation.

Chemical Speciation

BEIS uses two files related to chemical speciation. The first is the B360FAC file, which is a list of emission factors for each BELD4 vegetation type. The second is a GSPRO file, which provides a model species mapping. A typical biogenics GSPRO file includes biogenic species profiles for many mechanisms, but for CB6 modeling with currently released versions of CAMx and CMAQ, only the B10C6 profile is used. Note that CMAQ 5.3 has a new profile B10C6AE7 that accommodates a new version of the aerosol chemistry. If biogenic emissions are computed inline within CMAQ 5.3 instead of being merged in with the anthropogenic low-level emissions, CMAQ will use this profile automatically when needed.

Spatial allocation (for generating reports)

Spatial allocation of biogenic emissions is not based on spatial surrogates, but SMOKE still uses a spatial surrogate for the purpose of generating reports. The Smkmerge program reads in gridded biogenic emissions generated by the Tmpbeis3 program,and using the land area spatial surrogate to apportion each grid cell to one or more counties, estimates daily emissions totals by county which can then be used to generate emissions summaries. The land area spatial surrogate is input to SMOKE using variable name BGPRO and is the same as the spatial surrogate 340 used by anthropogenic sectors.

5. EMISSIONS PROJECTION METHODS

Biogenic emissions depend only on the meteorological year and land use, and therefore, are held constant in all future year projections.

6. EMISSIONS PROCESSING REQUIREMENTS

Biogenic emissions are processed for air quality modeling using the Sparse Matrix Operator Kernel Emissions (SMOKE[1]) modeling system, which includes an implementation of the BEIS model. Biogenic emissions with BEIS was run through SMOKEv4.6 using the sector name “beis”. BEIS uses SMOKE programs that are specific to the BEIS model. First, the Normbeis3 program is run, which is time-independent and processes gridded land use and emission factor data. Then, the Tmpbeis3 program reads in hourly meteorology and creates gridded hourly emissions. Finally, Smkmerge is used to generate reports as described in the Spatial Allocation section of Section 4. Because each day of biogenic emissions depends on the previous day by virtue of the gridded soil restart file (SOILINP), the beis sector must be run one day after the other in order; in other words, multiple months of the year cannot be run concurrently.

Even when running biogenics inline within CMAQ, it is still necessary to run the Normbeis3 program, since the B3GRD file output by Normbeis3 is required when running CMAQ with inline biogenics. The CMAQ inline biogenics option also requires the BIOSEASON file and the biogenic GSPRO. It is only necessary to run Tmpbeis3 when gridded hourly biogenic emissions will be input to CMAQ (the “offline” option). However, even when the plan is to run biogenics inline within CMAQ, we often run Tmpbeis3 and Smkmerge for the purpose of generating emissions summaries. Because different CMAQ modelers have different preferences with regard to how CMAQ is run, we often create two distinct sets of merged CMAQ-ready emissions: one set which includes biogenic emissions (for the offline option), and one set which does not (for the inline option).

[1] http://www.smoke-model.org/index.cfm

The beis sector is the only sector in the platform in which emissions are run separately for the spinup period (last 10 days of 2015) using actual meteorology for that time period. Merged emissions for the spinup period consist of biogenic emissions from December 2015 plus anthropogenic emissions from December 2016.
This is a 2-D sector in which all emissions are output to a single layer gridded emissions file.

7. Emissions Summaries

National and state totals by pollutant for the beta platform cases are provided here, and some example plots. Additional plots and maps are available online through the LADCO website[2] and the Intermountain West Data Warehouse[3].

These EPA emissions cases are marked as YYYYab where YYYY is the emissions year, the first lower case letter is the base year emissions modeling platform iteration and the second lower case letter stands for the nth set of emissions for the platform. Any YYYYe cases are based on the 2011-modeling platform while YYYYf cases are based on the 2014 NEI and related modeling platforms. The case descriptions are as follows:

2011en, 2023en, 2028el = Final 2011, 2023, and 2028 cases from the 2011v6.3 platform
Note that the same emissions for this sectror are used in all the 2011 platform cases.

2014fd = 2014NEIv2 and 2014 NATA

2016fe = 2016 alpha platform (grown from 2014NEIv2)

2016ff = 2016 beta platform

[2] https://www.ladco.org/technical/modeling-results/2016-inventory-collaborative/

[3] http://views.cira.colostate.edu/iwdw/eibrowser2016

Figure 3. Annual VOC emissions (tons/yr) from BEISv3.61 for the 2016beta inventory

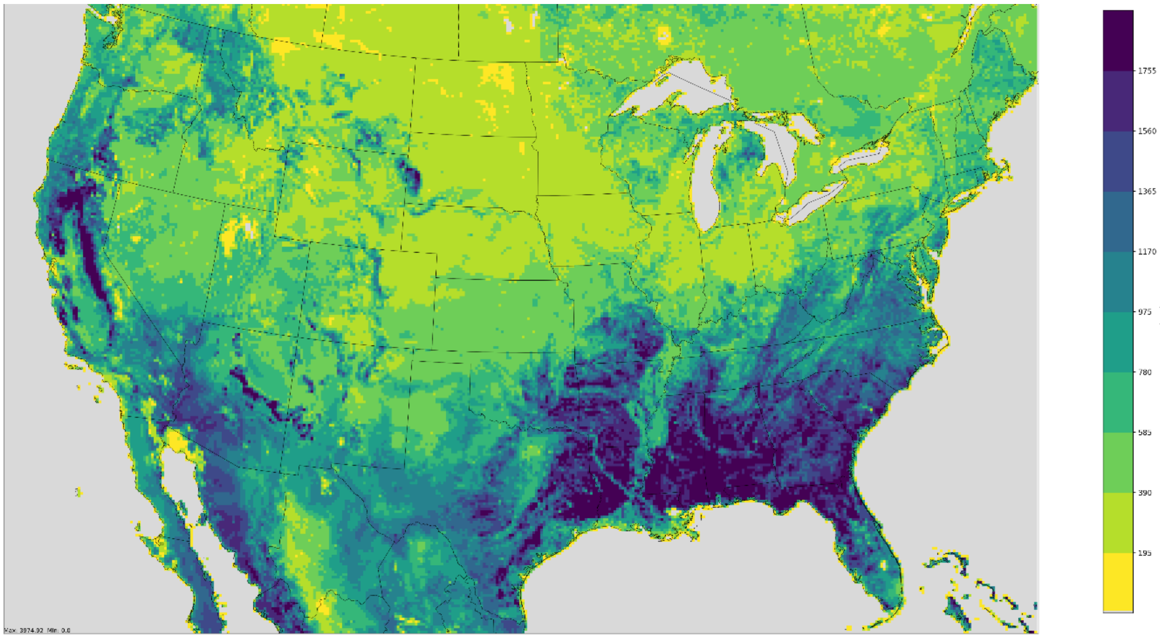


Figure 4. Annual Nitric Oxide (NO) emissions (tons/yr) from BEISv3.61 for the 2016beta inventory

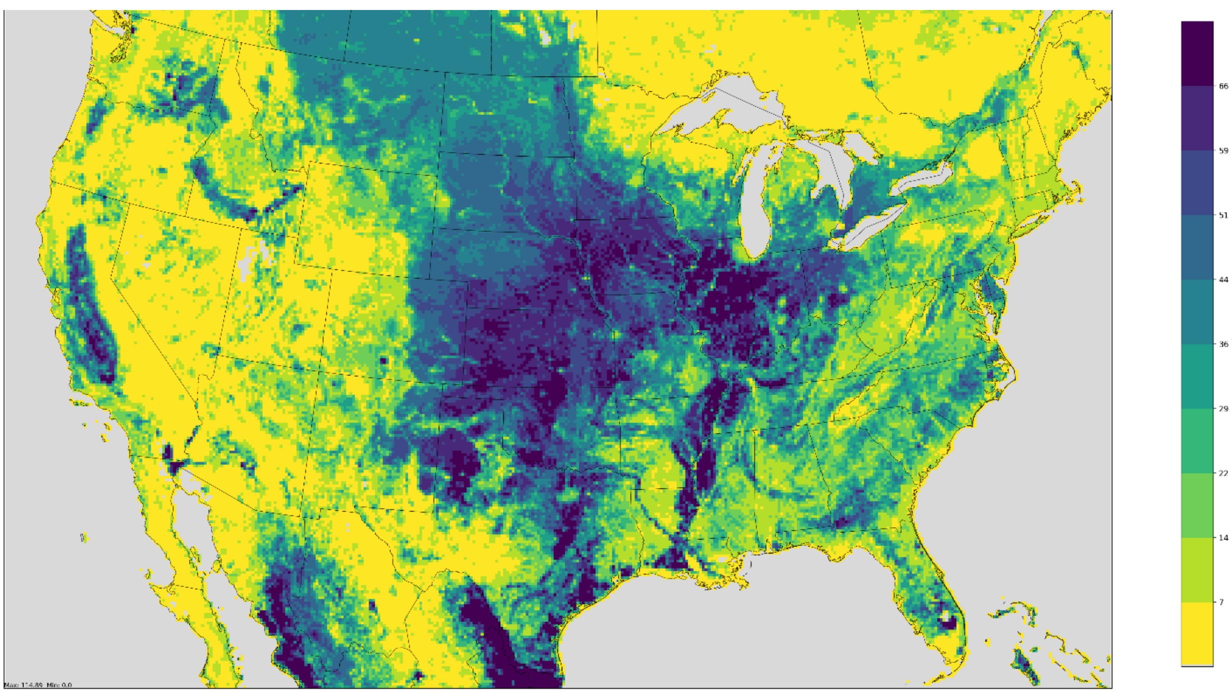


Table 2. Comparison of national total annual CAPS biogenic emissions (tons/yr)

Pollutant	2011en	2014fd	2016fe	2016ff
CO	7,183,342	6,654,275	7,296,894	7,163,806
NOX	912,702	903,150	979,205	966,421
VOC	42,795,239	38,671,686	42,861,181	42,095,853

Table 3. Comparison of state total annual NOx biogenic emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff
Alabama	12,421	12,006	12,834	12,575
Arizona	13,416	13,912	13,918	13,895
Arkansas	19,613	18,588	20,112	19,668
California	30,593	33,558	32,863	32,489
Colorado	31,237	31,489	33,418	33,328
Connecticut	606	576	620	598
Delaware	758	720	755	736
D.C.	13	12	13	13
Florida	14,895	14,543	15,145	14,630
Georgia	16,903	16,459	17,799	17,592
Idaho	14,094	15,263	15,459	15,353
Illinois	35,836	34,770	39,354	38,921
Indiana	21,016	19,314	21,576	21,381
Iowa	33,900	34,154	39,069	38,820
Kansas	53,133	53,623	59,337	58,938
Kentucky	15,394	14,361	16,073	15,882
Louisiana	13,428	12,862	14,114	13,576
Maine	2,472	2,413	2,509	2,373
Maryland	3,143	2,992	3,120	2,970
Massachusetts	910	869	928	873
Michigan	14,351	13,368	14,955	14,609
Minnesota	26,137	24,928	28,977	28,164
Mississippi	14,799	14,157	15,528	15,176
Missouri	33,611	32,909	36,289	35,888
Montana	44,875	45,558	49,492	49,222
Nebraska	44,143	45,713	49,311	48,957
Nevada	7,477	8,183	8,044	8,032
New Hampshire	693	658	707	688
New Jersey	1,334	1,255	1,326	1,283
New Mexico	30,307	30,210	30,844	30,813
New York	9,203	8,621	9,088	8,843

State	2011en	2014fd	2016fe	2016ff
North Carolina	14,345	14,026	14,762	14,487
North Dakota	31,075	29,691	34,522	33,619
Ohio	17,952	16,903	18,285	18,120
Oklahoma	38,746	37,854	40,897	40,375
Oregon	10,729	11,838	11,675	11,581
Pennsylvania	10,001	9,343	10,015	9,906
Rhode Island	166	160	169	149
South Carolina	7,922	7,715	8,208	8,044
South Dakota	37,805	37,116	43,351	42,372
Tennessee	14,674	13,857	15,154	14,902
Texas	103,288	100,855	108,341	107,283
Utah	7,656	8,221	8,301	8,226
Vermont	1,266	1,205	1,274	1,231
Virginia	9,280	8,807	9,349	9,166
Washington	11,760	12,790	12,818	12,584
West Virginia	3,791	3,582	3,877	3,845
Wisconsin	15,078	14,212	16,422	16,095
Wyoming	16,459	16,930	18,207	18,150

Table 4. Comparison of state total annual VOC biogenic emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff
Alabama	1,905,851	1,678,412	1,952,191	1,917,969
Arizona	1,797,794	1,850,673	1,880,113	1,876,773
Arkansas	1,684,121	1,339,614	1,571,655	1,544,135
California	2,245,889	2,668,491	2,578,106	2,555,377
Colorado	749,136	714,485	783,935	781,714
Connecticut	64,643	60,646	71,159	68,677
Delaware	27,243	21,963	26,147	25,255
D.C.	1,536	1,350	1,512	1,478
Florida	1,838,183	1,663,392	1,797,811	1,705,117
Georgia	2,068,091	1,779,264	2,060,926	2,032,688
Idaho	638,381	715,840	726,981	722,250
Illinois	440,546	362,766	430,688	422,736
Indiana	286,402	238,846	283,868	279,976
Iowa	273,969	230,569	281,694	278,977
Kansas	595,070	487,430	541,943	537,622
Kentucky	697,882	619,180	719,814	709,755
Louisiana	1,549,302	1,286,532	1,474,212	1,401,178
Maine	438,568	436,878	460,988	434,376
Maryland	174,254	142,009	171,090	157,380

State	2011en	2014fd	2016fe	2016ff
Massachusetts	104,270	97,681	114,638	107,668
Michigan	576,931	478,196	616,577	592,248
Minnesota	516,225	448,225	522,071	496,353
Mississippi	1,739,162	1,515,263	1,781,210	1,752,434
Missouri	1,210,290	1,001,575	1,172,490	1,158,094
Montana	890,232	891,011	953,043	946,676
Nebraska	348,185	326,438	376,383	373,398
Nevada	952,777	1,067,343	1,096,821	1,094,332
New Hampshire	109,681	104,257	116,474	113,311
New Jersey	116,029	102,877	119,064	114,470
New Mexico	1,391,405	1,256,514	1,327,669	1,326,002
New York	418,156	381,551	450,676	434,633
North Carolina	1,286,563	1,086,369	1,253,441	1,220,220
North Dakota	216,849	192,294	235,120	228,268
Ohio	340,817	295,523	364,900	360,156
Oklahoma	1,380,809	1,036,171	1,190,123	1,169,144
Oregon	897,648	1,109,627	1,063,117	1,056,293
Pennsylvania	506,300	439,424	538,655	532,770
Rhode Island	18,617	16,899	20,030	18,303
South Carolina	1,030,210	896,824	1,011,813	985,195
South Dakota	325,273	293,738	370,504	363,269
Tennessee	955,382	801,864	993,674	975,270
Texas	6,223,917	4,881,711	5,298,352	5,233,112
Utah	678,088	745,398	795,569	789,816
Vermont	84,791	79,525	88,301	86,437
Virginia	951,812	801,124	920,735	899,017
Washington	562,575	695,220	672,932	656,969
West Virginia	446,845	385,061	461,824	458,785
Wisconsin	480,085	406,127	502,169	484,780
Wyoming	558,452	539,515	617,975	615,002