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      United States, almost all of which are utility-scale. Utility-scale turbines are ones that
      generate power and feed it into the grid, supplying a utility with energy. They are usually
      much larger than turbines that would feed a homeowner or business. The regularly updated
      database has wind turbine records that have been collected, digitized, and locationally
      verified. Turbine data were gathered from the Federal Aviation Administration's (FAA) Digital
      Obstacle File (DOF) and Obstruction Evaluation Airport Airspace Analysis (OE-AAA), American
      Clean Power (ACP) Association (formerly American Wind Energy Association (AWEA)), Lawrence
      Berkeley National Laboratory (LBNL), and the United States Geological Survey (USGS), and were
      merged and collapsed into a single data set. Verification of the turbine positions was done by
      visual interpretation using high-resolution aerial imagery in ESRI ArcGIS Desktop. A locational
      error of plus or minus 10 meters for turbine locations was tolerated. Technical specifications
      for turbines were assigned based on the wind turbine make and models as provided by
      manufacturers and project developers directly, and via FAA datasets, information on the wind
      project developer or turbine manufacturer websites, or other online sources. Some facility and
      turbine information on make and model did not exist or was difficult to obtain. Thus,
      uncertainty may exist for certain turbine specifications. Similarly, some turbines were not yet
      built, not built at all, or for other reasons cannot be verified visually. Location and turbine
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      are field verified.</abstract>
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      spatially referenced, national dataset made up almost entirely of utility-scale wind turbine
      locations and their technical specifications. An appropriate use of the data would be for
      scientific analysis, research or for general interest for the public. Identification of
      turbines that have been retrofitted, repowered, decommissioned, and/or removed is a continual
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  States to March 2014". A description of the process to develop that dataset can be found in
  the metadata file for that release (https://doi.org/10.5066/F7251G8Q). Building off this
  earlier effort, the following steps were taken to expand and update the United States Wind
  Turbine Database (USWTDB) with the collaboration between USGS, LBNL, and ACP (formerly AWEA).
  Please note that some steps are iterated on a quarterly basis to keep the dataset current.
  (1) The March 2014 USGS dataset 48,956 turbines, 34,864 of which had unique FAA Obstacle
  Repository System (ORS) numbers was merged with (2) the LBNL wind turbine dataset. It had
  previously existed separately in house, and also had the FAA ORS number as well as many of
  the same fields as the USGS dataset. It was merged into the USGS dataset using the ORS
  number, bringing in LBNL fields and IDs. (3) Non-matching LBNL turbines were also added as
  LBNL only turbines. (4) The most recent FAA Digital Obstacle File (DOF) was downloaded and
  filtered for "windmills", and reprojected from WGS-84, as FAA provided it, to NAD-83 datum,
  the USGS and LBNL datum. These new coordinates were used later in the process. (5) The DOF
  dataset was then merged into the working USWTDB using ORS number, keeping new (non-matching)
  DOF Only turbines, and DOF variables (faa_aglht, faa_amslht, faa_asn, ylat, xlong). (6) The
  most recent FAA Obstacle Evaluation Airport Airspace Analysis (OE-AAA) file was downloaded
  and filtered for "windmills". (7) The OE-AAA dataset was merged into working USWTDB using
  Aeronautical Study Number (ASN) and preserved as the faa_asn attribute,keeping new (non-
  matching) turbines as OE only and OE-AAA variables (oe_builtdate, oe_appdate, oe_expdate,
  oe_comdate, notice of, status, dtrmntn, oe_aglht, ylat, xlong). (8) The latest ACP WindIQ
  turbine dataset was downloaded. (9) A geospatial match between ACP turbines and working
  USWTDB was performed using "geonear" command in Stata statistical analysis software and the
  following steps: [a] Save separate ACP and working USWTDB datasets. [b] Run "geonear" command
  in Stata between the two datasets to determine and "match" nearest neighbors (i.e., these
  turbines are suspected to be the same turbine but from the two different datasets), and
  calculate the distance between them. [c] Calculate differences in installed year, hub height,
  rotor diameter, and total height between "matched" turbine pairs. [d] Accept "match" (meaning
  assume they are, in fact, the same turbine) IF distance between pairs is zero (perfect
  geospatial match), OR distance between pairs is less than 100 feet (30.5 m) AND hub height,
  rotor diameter, and installed year are equal between the pairs. If the match criteria were
  not met, both turbines in the pair were saved for subsequent visual inspection and "manual"
  confirmation of match. Non-matching ACP turbines are added to the dataset as ACP-only
  turbines and all ACP variables (turbine ID, p_year, t_cap, t_hh, t_rd, t_tth, ylat, xlong,
  t_manu, t_model, t_state, retrofit, retrofit_year, as well as other variables) were added to
  the dataset. (10) A hierarchy was developed because multiple datasets contain some of the
  same fields (e.g., t_ttlh was contained in USGS, LBNL, DOF, OE-AAA and ACP datasets)Because
  LBNL and ACP data are sourced from two high-quality sources (OEMs and developers) and
  reconciled to eliminate differences, LBNL data is the primary source for turbine attributes
  and turbine project characteristics, then ACP, USGS, DOF, and finally OE-AAA. In the
  overwhelming majority of cases, differences between sources were minimal, but when
  discrepancies existed that order was used to populate fields. All fields that are missing
  from higher-order sources are populated from lower sources. (11) The working (i.e., fully
  merged) USWTDB was spatially joined with base layers via ArcMap in order to pin t_state,
  t_county and t_fips to turbine points. (12) Turbine points were selected by state, saved as
  an individual turbine file for each state, and distributed to authors for editing. (13) A
  basemap image from Digital Globe was added to the ArcMap project file. If Digital Globe
  imagery did not show a turbine installation, USDA/NAIP County Mosaic Orthoimagery Google
  Earth imagery was cross checked. Previous bing map image source was retained for some of the
  previous USGS data. (14) Turbine points were visually verified and edited/moved to the base
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      of the turbine as needed with an estimated tolerance of 10 meters. (15) If the turbine data point was not seen on an image, the t_conf_loc was entered as 1. If the turbine point was in partial construction or with other doubts, the t_conf_loc was entered as 2. If a turbine was clearly seen on image, the t_conf_loc was entered as 3. Turbines that have not yet been visually verified are labeled with 0 in t_conf_loc. (16) Turbine points that had existed previously but were since decommissioned and removed were flagged as decommissioned and later removed (see step 20). (17) Duplicate turbine points (largely resulting from ACP geospatial merge) were identified and t_img_date, and t_img_srce were attributed for each turbine. (18) Non-turbine points that had been assigned FAA Obstacle Repository System (ORS) numbers or were digitized in the process such as communications towers, meteorological towers, water windmills, power transmission towers, etc., were removed. (19) Edited wind turbine files for each state were merged into one single shapefile, turbines identified as duplicates were matched, all fields were collapsed into a single turbine observation, and duplicate points were removed. (20) Turbines flagged as decommissioned were removed. (21) QA/QC was conducted for spatial accuracy and attribution by a peer or a supervisor other than the author that initially completed the work. As noted above, steps 4-21 are repeated on a quarterly basis, using the most recent USWTDB as the starting point. (22) Starting with version 2_3, an additional attribute of the eia_id 860 plant code was added to allow users to correlate to EIA 860 data. The plant codes were initially matched to ACP base data when available and provided by ACP. The incomplete values were matched manually based on project name, year, turbine make/model, state, county, etc. (23) Starting with version 3_3, two additional attributes were added from ACP data to identify turbines that have been partially retrofit (i.e., new rotor blades and/or nacelles on existing towers) named retrofit and the year in which that retrofit occurred named retrofit_year. This information is derived from ACP's WindIQ database. (24)A csv of the data is then exported, as well as creation of a changelog, and entity and attribute data dictionary; all can be downloaded separately.</procdesc>
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  <attrdef>name of the wind power project that the turbine is a part of</attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <udom>Project names are typically provided to ACP (formerly AWEA) by the developer; some
    names are identified from other website search resources, and others are created by the
    authors to differentiate them from previous projects. If no project name can be identified
    via these methods, authors assigned one based on the county where the turbines are located.
    </udom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>p_year</attrlabl>
  <attrdef>Year the wind power project became operational and began providing power. In some
  cases, the year is estimated based on the year the turbine was erected, which will precede
  when it became operational, and sometimes fall in the preceding year; -9999 values in the
  shapefile and blank values in the csv are unknown</attrdef>
  <attrdefs>Producer defined</attrdefs>
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      <attrunit>Year</attrunit>
    </rdom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>p_tnum</attrlabl>
  <attrdef>number of turbines in the wind power project</attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <rdom>
      <rdommin>1</rdommin>
      <rdommax>713</rdommax>
      <attrunit>Count</attrunit>
    </rdom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>p_cap</attrlabl>
  <attrdef>cumulative capacity of all turbines in the wind power project, in megawatts (MW);
  -9999 values in the shapefile and blank values in the csv are unknown</attrdef>
```

```
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <rdom>
      <rdommin>0.05</rdommin>
      <rdommax>1055.6</rdommax>
      <attrunit>Megawatts</attrunit>
    </rdom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>t_manu</attrlabl>
  <attrdef>turbine manufacturer - name of the original equipment manufacturer of the
  turbine</attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <udom>E.g., Vestas, Siemens, Suzlon, etc.; "missing" values in the shapefile and blank
    values in the csv are unknown</udom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>t_model</attrlabl>
  <attrdef>turbine model - manufacturer's model name of each turbine</attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <udom>E.g., 1.5SLE, V100_1.8, Z50, etc.; "missing" values in the shapefile and blank values
    in the csv are unknown</udom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>t_cap</attrlabl>
  <attrdef>Turbine rated capacity in kilowatt (kW). The manufacturer's stated output power at
  rated wind speed. Data from ACP (formerly AWEA), manufacturer data, and/or other internet
  resources; -9999 values in the shapefile and blank values in the csv are unknown</attrdef>
  <attrdefs>Producer defined</attrdefs>
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      <rdommax>6000</rdommax>
      <attrunit>kilowatt</attrunit>
    </rdom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>t_hh</attrlabl>
  <attrdef>turbine hub height in meters (m). Data from ACP (formerly AWEA), manufacturer data,
  and/or other internet resources; -9999 values in the shapefile and blank values in the csv
  are unknown</attrdef>
  <attrdefs>Producer defined</attrdefs>
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      <rdommin>19</rdommin>
      <rdommax>137</rdommax>
      <attrunit>meter</attrunit>
    </rdom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>t_rd</attrlabl>
  <attrdef>turbine rotor diameter in meters (m); -9999 values in the shapefile and blank values
  in the csv are unknown</attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <rdom>
      <rdommin>13.4</rdommin>
      <rdommax>162</rdommax>
```

```
      <attrunit>meter</attrunit>
    </rdom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>t_rsa</attrlabl>
  <attrdef>turbine rotor swept area square meters (m^2); -9999 values in the shapefile and
  blank values in the csv are unknown, calculated as 3.14159 (([rotor_dia] /2)*([rotor_dia] /2)
  </attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <rdom>
      <rdommin>141.03</rdommin>
      <rdommax>20612</rdommax>
      <attrunit>square meter</attrunit>
    </rdom>
  </attrdomv>
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<attr>
  <attrlabl>t_ttlh</attrlabl>
  <attrdef>turbine total height - height of entire wind turbine from ground to tip of a
  vertically extended blade above the tower. Computed as the hub height plus half of the rotor
  diameter, in meters, when t_hh and t_rd are non-missing. Otherwise, the total height as
  provided by the FAA DOF or FAA OE/AAA is used, which can be considered a maximum height;
  -9999 values in the shapefile and blank values in the csv are unknown</attrdef>
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      <attrunit>meter</attrunit>
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  </attrdomv>
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  <attrdef>Indicator of whether the turbine has been partially retrofit after initial
  construction (e.g., rotor and/or nacelle replacement).</attrdef>
  <attrdefs>Producer defined.</attrdefs>
  <attrdomv>
    <edom>
      <edomv>0</edomv>
      <edomvd>No known retrofit.</edomvd>
      <edomvds>Producer defined</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
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  </attrdomv>
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<attr>
  <attrlabl>retrofit_y</attrlabl>
  <attrdef>Year in which the turbine was partially retrofit.; -9999 values in the shapefile and
  blank values in the csv are typically not retrofit or the year of retrofit is unknown.
  </attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <rdom>
      <rdommin>2015</rdommin>
      <rdommax>2021</rdommax>
      <attrunit>Year</attrunit>
```

```
    </rdom>
  </attrdomv>
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<attr>
  <attrlabl>t_conf_atr</attrlabl>
  <attrdef>Level of confidence in the turbine's attributes, from low to high</attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
    <edom>
      <edomv>1</edomv>
      <edomvd>no confidence: no information found</edomvd>
      <edomvds>Producer defined</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
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      <edomv>2</edomv>
      <edomvd>partial confidence: incomplete information or discrepancies across data sources
      or other issues found</edomvd>
      <edomvds>Producer defined</edomvds>
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  </attrdomv>
  <attrdomv>
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      <edomv>3</edomv>
      <edomvd>full confidence: consistent information across multiple data sources</edomvd>
      <edomvds>Producer defined</edomvds>
    </edom>
  </attrdomv>
</attr>
<attr>
  <attrlabl>t_conf_loc</attrlabl>
  <attrdef>Level of confidence in turbine location, from low to high</attrdef>
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  <attrdomv>
    <edom>
      <edomv>1</edomv>
      <edomvd>no confidence: nothing on image, image has clouds, never built, previously
      removed, needs newer imagery</edomvd>
      <edomvds>Producer defined</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>2</edomv>
      <edomvd>partial confidence: image shows developed pad with base and/or turbine parts on
      ground</edomvd>
      <edomvds>Producer defined</edomvds>
    </edom>
  </attrdomv>
  <attrdomv>
    <edom>
      <edomv>3</edomv>
      <edomvd>full confidence: image shows an installed turbine or tower being constructed, the
      tower is least partially present with neighboring turbine constructed</edomvd>
      <edomvds>Producer defined</edomvds>
    </edom>
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  <attrdef>date of image used to visually verify turbine location (note if NAIP is the image
  source the month and day were set to 01/01)</attrdef>
  <attrdefs>Producer defined</attrdefs>
  <attrdomv>
```

```
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        <rdommax>11/3/2023</rdommax>
        <attrunit>date</attrunit>
      </rdom>
    </attrdomv>
  </attr>
  <attr>
    <attrlabl>t_img_srce</attrlabl>
    <attrdef>source of image used to visually verify turbine location</attrdef>
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        <edomvd>ESRI ArcMap Base maps, available from ESRI ArcMap</edomvd>
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    <attrdomv>
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    </attrdomv>
    <attrdomv>
      <edom>
        <edomv>Google Earth</edomv>
        <edomvd>https://www.google.com/earth/versions/#earth-pro</edomvd>
        <edomvds>Producer defined</edomvds>
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        <edomvd>National Agriculture Imagery Program County Mosaics from
        https://datagateway.nrcs.usda.gov/</edomvd>
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    </attrdomv>
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    <attrlabl>xlong</attrlabl>
    <attrdef>current longitude of the turbine point, in decimal degrees calculated in Arc Map
    using GCS: North American 1983 (NAD 83)</attrdef>
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        <rdommin>-171.713074</rdommin>
        <rdommax>144.722656</rdommax>
        <attrunit>decimal degrees</attrunit>
      </rdom>
    </attrdomv>
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    <attrlabl>ylat</attrlabl>
    <attrdef>current latitude of the turbine point, in decimal degrees calculated in Arc Map
    using GCS: North American 1983 (NAD 83)</attrdef>
    <attrdefs>Producer defined</attrdefs>
    <attrdomv>
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        <rdommin>13.389381</rdommin>
        <rdommax>66.839905</rdommax>
        <attrunit>decimal degrees</attrunit>
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