DATA BASE DESCRIPTION AND RESEARCH METHODOLOGY
UDI WORLD ELECTRIC POWER PLANTS DATA BASE

The UDI World Electric Power Plants Data Base (WEPP) is a comprehensive global inventory of electric power generating units. It contains ownership, location, and engineering design data for power plants of all sizes and technologies operated by regulated utilities, private power companies, and industrial or commercial autoproducers in every country in the world.

The WEPP is maintained and re-issued quarterly in its entirety (including regional subsets) by the UDI Products Group of Platts, the energy information division of The McGraw-Hill Companies, Inc.

The current version of any of the WEPP Data Base documentation is always the most authoritative and supersedes all previous versions.

ACKNOWLEDGMENTS AND CONTACT

The assistance of the organizations that have provided surveys, reports, and other information is gratefully acknowledged.

Any data base corrections or updates are welcome and should be directed to Christopher Bergesen, Editorial Director, UDI Products, in Platts' Washington, DC offices (fax: 202-942-8789; email: udi@platts.com)

LEGAL STATEMENT

The accompanying document entitled ***COPYRIGHT AND DISCLAIMER - UDI WORLD ELECTRIC POWER PLANTS DATA BASE*** is hereby incorporated into this documentation by reference.

WEPP METHODOLOGY CONTENTS

This document has the following sections:

DATA BASE HISTORY AND FORMAT

The first WEPP precursor was a U.S. utility-owned power plant data base started in 1978 at the Atomic Industrial Forum, a trade association based in Bethesda, Maryland, with joint funding from the U.S. Department of Energy and the Utility Water Act Group (UWAG), a power company advocacy organization. Overseas power plant data collection began in 1984 and the first international plant directory was published in 1990. The first stand-alone data set with essentially the current structure was published in March 1998.

The WEPP is sold as a flat data file in dbf (dBase III) format. The file opens directly with Microsoft Excel software and can also readily be imported into Microsoft Access or other data-management software. Due to the size of the complete generating unit file, it will not completely load in single spreadsheets of older Excel versions. Separate regional subsets with identical field structures have been created: these can be used directly in all Excel versions.

The WEPP data file directory (DFD) is maintained as a separate document. This includes field names, types, lengths, and a brief description of field content.

DATA BASE ORGANIZATION

Information in the WEPP Data Base is included at the company, plant, and unit levels. Company data include the company name, electric type, and business type (see next section). There are three electric types:

U = regulated utility, also includes much of the electric generating capacity owned by national or local government ministries, agencies, and departments

A = autoproducer, an industrial or commercial enterprise generating its own electricity typically without off-site energy sales, although the facility may be grid-connected (autoproducer generators are also known as inside-the-fence or captive power plants)

P = private, independent power plant (IPP), or merchant plant developer, also includes utility-built capacity sold to third parties

Plant location data include the city, state or province, country, geographic area, and subregion. Most territories and other dependencies are treated in the data base as separate countries. For plants in North America, the North American Electric Reliability Corp (NERC) region is listed as the sub-region.

Unit data include unit name, operating status, capacity (MWe), year-on-line, primary and alternate fuels, equipment vendors for the boiler (or reactor), turbine and/or engine, and generator/alternator, steam conditions, pollution control equipment, engineering and construction contractors, and cooling system data. See “Model Numbers” below for further discussion of coding used for prime mover and steam generator types.

DATA BASE COVERAGE

The WEPP Data Base covers electric power plants in every country in the world and includes operating, projected, deactivated, retired, and cancelled facilities. Global coverage is comprehensive for medium- and large-sized power plants of all types. Coverage for wind turbines, diesel and gas engines, photovoltaic (PV) solar systems, fuel cells, and mini- and micro-hydroelectric units is considered representative, but is not exhaustive in many countries. Many facilities of less than 1 MW are listed, but generating units of less than 1 kW are not included.

Mechanical-drive steam turbines, gas turbines, and reciprocating engines are not included in the WEPP, nor are central heating plants without electricity output, power generating equipment on offshore oil and gas production platforms, and most short-term rental units. Some “temporary” rental plants have stayed in service for years and these are included where data are available.

Reciprocating (IC) engines or gas turbines identified in primary sources as "emergency," "standby," "backup," or “black-start” are included where data are available. Status for these machines is generally shown as OPR (operational) even though they typically operate for load very infrequently. Emergency diesel sets at nuclear power plants are typically not included in the data base.

See ***Appendix A*** for more details on data base coverage by plant technology and size. Also, see below under “Small Plants and Distributed Generation” and “Wind and Solar Energy Plants.”

RESEARCH OVERVIEW AND INFORMATION SOURCES

Over the last 30 years, UDI staff have witnessed great changes in the sourcing and compilation of information for its data sets. Originally, written or telephone inquiries resulting in typed letters and data tables were the rule. The introduction of the fax machine and more reliable overseas telecommunications were a great advance. Finally, the development of the worldwide web and computer-based communications and imaging technologies enabled a quantum increase in the amount and timeliness of material available for review.

As the amount of information available for review increased, so too did the absolute size of the electric power industry, the number of power plants, and the types of generating technologies. This made it imperative to continue to focus on the most relevant information for data base users. Fortunately, the original data base design proved sufficiently inclusive and flexible so that only very modest changes have been required since the current format was first established in the early 1990s.

For the last two decades, the WEPP data base research process has remained essentially the same. UDI staff scan the trade and business press daily and, more recently, are alerted to possibly relevant material by web-based tools. In addition, great quantities of historical information are available on the web and/or in lists and other documentation already in UDI's collection and these are consulted on a continuing basis. From these primary and secondary data base sources, power plant data are extracted, entered, and verified to the extent possible. A direct inquiry to plant operators or suppliers is often sent following initial data entry and/or when new plants are brought online or expected in service.

Updates (or possible updates) to plant-level or unit-level data in the WEPP are essentially of two varieties, those requiring the addition of new records to the data base and those requiring updates to existing records.

For new records, the first step is to ensure that the facility and/or the plant operator are not already in the data base under different names. This process can take some time, particularly if the source information is in a foreign language, fragmentary, or otherwise obscure. Once it is established that the plant is new to the data base, the record is created. Oftentimes, the result is both a new WEPP company record, a new plant record, and a new unit record. For larger power stations, the initial data entry process is usually accompanied by a web search for additional information. Typically, at this stage, such queries are completed to establish more precise geographical location or ownership, the number of generating units, deployment schedule, and equipment suppliers. For small plants (usually in the sub-5 MW size range), multiple records are often added for an operator as a website list of references for the operator or equipment supplier is frequently uncovered during the query process.

While many new records are added to the WEPP (usually over 1,500 per quarter), it is more common to update existing records. In part the process is the same as with the addition of new records, that is the plant must be identified and baseline information checked. The update may be significant (ownership, service year, status, fuel, or suppliers) or relatively minor (modest change in capacity rating, coal rank, turbine model number, cooling system, etc.). As with the new record addition process, it is often the case that one or more other unit records can be updated at the same time. This happens when, for example, a list of references for engineering services or pollution control equipment is uncovered.

As noted, power plant data are obtained from numerous sources. These include direct surveys, vendor reference lists, power company financial and statistical reports, and the trade and business press. Primary sources such as surveys and materials directly produced by owners, operators, and suppliers are used preferentially:

- ❑ Reliable information on new and existing power plants is often obtained by direct survey. To this end, plant-specific queries are sent on a continuing basis to utilities, autoproducers, private-power companies, and suppliers around the world.

- ❑ Annual reports, statistical supplements, web pages, press releases, and other public relations materials provided by power plant operators or equipment and service suppliers are a second primary data source.

- ❑ Experience lists (also termed reference or installation lists) are a third primary data source. Over 350 equipment and service supplier lists are available for use in the WEPP Data Base research and new and updated lists are frequently obtained from the web or by direct request. Data extracted from the lists are manually cross-checked against existing records in the data base to minimize duplication.

- ❑ Trade and business press sources include newsletters, newspapers and magazines, papers from professional meetings, and yearbooks and directories. Oftentimes, such references provide only one piece of information for a power plant or generating unit, but these references are usually reliable and timely.

UNIT CONFIGURATION AND CODING CONVENTIONS

With some exceptions as noted below, the WEPP Data Base includes information on a generating unit basis whenever possible. A "unit" may be termed a set, block, aggregate, or section in other sources. Unit names in the WEPP are unique.

- ✓ For typical steam-electric plants, a unit is comprised of a steam generator (boiler or reactor), a steam turbine (the prime mover), and a generator. In cases were a series of boilers are connected to a common steam header, the unit designations are applied to the prime movers and the boiler-related data are assigned to the unit records as appropriate. In some instances, a single boiler or reactor drives two identical turbine-generator (T/G) sets. In an analogous situation, two identical steam-electric boilers may drive a single T/G set. In each of these instances, there is a single unit record posted in the data base.

- ✓ For simple-cycle frame and aeroderivative gas turbines, a unit consists of the gas turbine (GT) and generator. Note that *gas turbine* (gaseous fuels) and *combustion turbine* (liquid fuels) are considered synonymous in the data base. Pairs of gas turbines driving single generators are not identified by a separate UTYPE designation and this machine configuration is considered a single unit.

- ✓ Combined-cycle gas turbine units (CCGT), cogeneration units, and combined heat-and-power (CHP) units typically add a fired or unfired waste heat recovery steam generator (HRSG) behind a gas turbine. The HRSG may in turn drive a steam turbine or may only generate process steam or hot water for heating or industrial applications. HRSG supplier is usually not be listed unless there is steam production for a steam-electric turbine-generator set (also see below under "Capacity Rating," "CHP and Cogeneration," and "Repowering").

- ✓ Combined-cycle units are typically built in configurations abbreviated as 1+1, 2+1, 3+1, 3+2, or 4+1. The 2+1 configuration, for example, includes two GTs each followed by a single HRSG with the two HRSGs supplying one steam T/G set. Gas turbines and steam turbines in combined-cycle are shown with UTYPE of GT/C and ST/C, respectively, and data for each prime mover are listed separately where data are available. Single-shaft combined-cycle units have a gas turbine and a steam set driving the same generator and are given their own abbreviation in the data base (CCSS). For single-shaft units, the capacity (MWe) of the gas and steam turbines are aggregated and not otherwise listed separately.

- ✓ In hydroelectric plants, a unit is considered to be a hydraulic turbine and attached generator. If two turbines drive a single generator, this array is considered a single unit.

- ✓ For internal combustion (IC) units (reciprocating gas and diesel engines), a unit is an engine and a generator/alternator. In many cases, waste-heat is taken off IC engines for district heating or other purposes (cogeneration), and, in some cases, this is used to generate steam and drive steam-turbines in combined-cycle. Both instances are coded separately. In some cases where large numbers of identical, containerized engines have been installed, these may be listed as a single “unit” with the number of engines indicated.

- ✓ For microturbine plants, the "unit" record consists of same-model gas turbines installed at the same time. If known, the number of machines is indicated in the unit name (for example, MICROTURBINE PLANT GT 1-12).

- ✓ For wind energy plants, the "unit" record consists of wind turbine generators (WTG) of the same model installed at the same time. If known, the number of machines is indicated in the unit name (for example, WIND PLANT WTG 1-8). There are frequently series of WTGs of different size, design, and ownership installed at the same site and these are usually listed separately. Also see below under “Wind Energy and Photovoltaic Plants.”

- ✓ Photovoltaic (PV) plants and fuel cells (FC) are not unitized, although installations of different vintage or with different suppliers may be listed separately. The generating capacity of PV power plants is peak electric output (kWp). Also see below under “Wind Energy and Photovoltaic Plants.”

POWER COMPANY AND POWER PLANT NAMES

Where possible, the full name of utilities, autoproducers, IPPs, or other plant operators are used. Otherwise, names are abbreviated to fit data base coding conventions.

The decision to list multinational operating companies as one company or as separate companies is made on a case-by-case basis. With the proliferation of overseas investments by large utility or energy groups, the trend has been towards uniquely identifying subsidiaries or affiliates operating in various countries or regions.

Wind turbines, mini- and micro-hydroelectric plants, diesel engines, and solar power plants are often installed by individuals or small private companies of various kinds. If the specific identity of the owner cannot be established, the operating company may be shown as “XXX Hydro Project,” “XYZ Plant,” and so on. Also, see below under “Wind Energy and Photovoltaic Plants.”

Many power plants have both formal and informal names, the former may be a person's name, for example, while the latter is the name of the plant locality. The WEPP usually uses the formal plant name, but may indicate another name in common usage. Where specific unit names are not available, geographic location is most often used to name the plant for inclusion in the data base. To the extent possible, the plant name in the local language is used. Plant names in the WEPP are unique and addition of a location, operator acronym, or other identifier as part of the plant name is required when there are multiple occurrences of the same plant name.

Plant names in the data base may change in a variety of circumstances: when the operator changes the name, to clarify distinctions between plants with similar names, to preserve the plant's unique identification in the data base, or to more closely align nomenclature with that used in primary source documentation.

For the designation of individual units at a given power station, power companies may use a unit numbering scheme (1, 2, etc.), an alphabetic scheme (Block A, B, etc.), Roman numerals (I, II, III, and so on), or various combinations of the same. Letters are often used to indicate the development of new unit series at existing sites -- Plant "A1" and "A2" followed by Plant "B1" or such schemes as Plant "One", Plant "Two", Plant "New", Plant-1, Plant-2, etc. Some countries use both a letter designation (indicating a fundamental change in design) and a sequential unit numbering scheme.

Unit numbers in the WEPP are preferentially those assigned by the plant operator to the prime movers or are assigned to the prime movers on a sequential basis. The decision to combine unit records at a particular site may be somewhat arbitrary. In general, physical proximity of plant infrastructure or shared common facilities such as cooling water structures or switchyards suffices to group units of different types and/or vintages at the same site into a single plant. Note that in some cases, units are split into separate sites due to different ownership. Unit-level assignments to plant records can and do change over time.

If precise, unit-level data are not available, but a particular number of units are known to be in service, this is shown as, for example, PLANT NAME 1&2. Plant data are unitized whenever possible with the exceptions noted.

Absence of a unit designation indicates that it is not known whether the generating capacity shown represents one or more than one individual unit. In some cases, research has established the presence of existing capacity of unspecified configuration to which new equipment has been added. In these instances, the original plant record may be shown as PLANT NAME (A) or PLANT NAME (B) (depending on the vintage of the unspecified block) with the plant extension shown in unitized form as PLANT NAME-1, PLANT NAME-2, etc.

Industrial power plants are often shown with FACTORY, PLANT, MILL, REFINERY, WORKS, etc., as part of the plant name.

By convention, gas turbine unit names in the data base usually include the designation "GT", steam turbines in combined-cycle show "SC" prefixes, diesels show "IC", fuel cells have "FC", photovoltaic systems show "PV", waste-to-energy plants show “WTE,” and wind turbines "WTG". Some hydroelectric plants include “HY” as part of the unit name and “CC” may be used for combined-cycle plants.

With very rare exceptions, periods and commas are not used in WEPP company or plant names. International lettering is never used.

POWER PLANT OWNERSHIP

The WEPP data base has a single field – COMPANY – for power plant owners. As a general matter, the listed company is both the facility operator and sole <u>or</u> majority owner. However, there are many variations, including dedicated utility operating companies with one or more plants, third-party operation and maintenance (O&M) and service companies, government agencies with small power generators, industrial companies for which power stations are a minor business at large refineries, smelters, and so on.

The assignment of a particular power plant to a particular company can and does change over time. In addition, and as noted above, the name of the companies and plants can change as well, further complicating coverage for this field in the data base.

Many power stations, particularly large nuclear, coal, and hydroelectric plants, are jointly owned. Increasingly, the owners may include a mix of power companies and other parties, such as fuel or manufacturing companies, investment funds and financial institutions, and national or local government authorities of various kinds. <u>The WEPP data base does not track joint ownership shares</u>.

Also see below under “Wind Energy and Photovoltaic Plants” for ownership background information specific for these technologies.

CAPACITY RATINGS

The WEPP capacity value is preferentially gross megawatts electric (MWe). In many cases, no defined value is available so the data base includes whatever value is included in the primary source documentation. Capacity ratings are poorly standardized across the industry, frequently differ from source to source, and can and do change with some frequency.

If re-rating data are available after a unit is modernized or otherwise modified, new capacity values are entered in the data base without making any changes to service year or suppliers (also see below under “Repowering”.)

PLANT STATUS

The completion of new power stations or changes in the operating status of installed plant are often not publicized, particularly for smaller installations. Even if announced, the actual situation may be somewhat obscure.

When a power plant is released for regular operation, the WEPP status code is changed to OPR. There are different phrases used to signify operability. “Commercial operation” is often used for utility-owned plants, and this is taken to mean that new plant is available for full-load service per applicable regulatory guidance. Another common phrase is “turn-over”, which occurs when the contractors turn-over the power station to the operators for full-time operation. In the case of large-size central stations, there is often a contractually-defined testing period, after which the facility is placed in commercial operation.

In all instances, a dedication or other official opening ceremony may be held well after the new plant is in operation.

There are many instances where the WEPP unit status is shown as OPR or STN and yet the facilities are in fact offline, either temporarily or for extended periods. Not infrequently, nuclear units may be offline for one or more years for safety modifications or other technical reasons while large thermal and hydroelectric units can be shutdown for equipment retrofits and so on. These units are generally shown in the data base as OPR regardless. If the operating company indicates that a facility is “mothballed,” the WEPP code DAC (deactivated) is usually used.

Another difficult aspect of the research involved in maintaining the WEPP Data Base has to do with the status of older generating units. It is not uncommon for hydroelectric units to run for 70 years or more, basically with the original equipment. Many steam-electric units have run for over 50 years and, depending on loading and other factors, diesel engines and gas turbines can remain operational for many decades. The phrases “decommissioned,” “deactivated,” and “shutdown” are used interchangeably by power companies and the trade press alike. Even plants that have been formally retired may come back into operation and it is only when a plant is demolished and/or the generating equipment scrapped that the facility can be said to be definitively removed from service.

Some older units in the WEPP Data Base are shown with status of UNK (unknown). There is a good likelihood that these units are now offline, but more definitive information is not yet available.

As with other fields in the data base, when new status information becomes available, the records are updated immediately.

SERVICE DATES FOR NEW PLANT

A topic of interest to many users is the year of expected operation of new generating resources. The number of projects cumulatively proposed for a particular year is always less than the number of projects completed, and this is true irrespective of unit size or technology. Just as many announced projects are never completed, it is often the case that the expected year of operation at the time when a project is announced slips forward in time, although plants are also completed ahead of schedule.

The service year is often difficult to establish and “completion” dates of generating units as shown in the data base may lag actual operation by one or more years. Unit-specific data obtained from power companies or other primary sources are preferentially used to establish the operation year.

There are many data base records for projected plant where the year-on-line is blank, indicating that no reliable completion estimate is readily available. Schedules naturally firm as permitting is completed, equipment is ordered, and construction starts. This makes data for the near-term (3-5 years) more reliable that data for plants expected online in out-years.

Another factor to consider is plant size and technology. Larger projects have longer lead times, and thermal, nuclear, and hydroelectric plants have longer lead times than plants using technologies allowing for a larger amount of modular fabrication and assembly, such as gas turbines and IC engines. This allows for somewhat more accurate, medium-term enumeration of expected service dates for larger, more complex projects as opposed to small thermal, hydro, or renewable plants.

In cases where only main equipment order dates are available for larger steam-electric and hydraulic units, the data base has a year-in-service date of three years after the order date. For gas turbines, the data base uses a two-year construction duration estimate. For engines and small hydro units, service year is assumed to be order or delivery year.

NEW PROJECTS

Traditionally, the construction of large power projects in fully-developed economies was driven by requirements to replace older plants and meet load, thus imparting a cyclical nature to the deployment of new plant as large-capacity units were added in step-wise fashion. In developing countries, the construction of new power plants is generally driven by rapid increases in load growth, in turn largely a function of overall economic development, and the availability of funding.

More recently, shifts in the cost and availability of fuel and local or national policy directives have been added as key drivers for new plant construction and the plant size and technology mix has shifted in many markets. It has become increasingly difficult to establish the boundaries of the sequential construction cycles as larger integrated markets are formed (as in Europe, for example) or as new policy imperatives come to the fore (climate change initiatives being the most prominent at present).

The decision to include new power projects in the WEPP Data Base is important for users and the decision to add a new project to the file is made on a case-by-case basis. Key determinants in approximate order of importance are: 1) order placement for generating equipment or engineering, procurement, and construction (EPC) services, 2) the status of licensing or permitting activities, 3) funding, and 4) the availability of fuel or transmission access. Projects may also be included even if such data are lacking if there are generalized national or regional policies that are driving power plant development.

The WEPP status codes for new projects are CON = under construction (physical site construction is underway), PLN = planned (still in planning or design), DEF = deferred (no longer scheduled), DEL = delayed (construction was started but later halted).

GEOGRAPHIC INFORMATION

To the extent possible, the formal names or abbreviations for states, provinces, counties, etc., are used according to international standard ISO 3166 and/or usage by the Universal Postal Union. The Statoids website (www.statoids.com) is a comprehensive and useful reference for such geographic data. The geographic information fields are being retroactively populated as research time permits.

As noted, dependencies and territories are usually listed as if they were separate countries. Sub-national political subdivisions are referred to by many names such as state, province, department, canton, prefecture, county, and so on. On occasion, there are wholesale revisions to state or provincial names used in the WEPP Data Base.

City, state, and country names are generally anglicized according to common usage. Note that many electric power plants are located far from population centers and, as a result, the listed “city” can be at some considerable distance from the actual plant site. Also, the listed city may well be a town, municipality, township, commune, district, village, or another type of political subdivision.

ABBREVIATIONS FOR VENDORS AND DESIGN DATA

By some measures, electric power is the world’s largest industrial sector. This is reflected in the very large number of companies that supply equipment and services to power companies. Advances in technology and changing policies have likewise resulted in a proliferation of fuels and electricity production technologies.

Over 25+ years of operation, data base coding and abbreviating conventions have naturally been modified and necessarily expanded to reflect this industrial diversity and the WEPP List of Abbreviations now has over 8,100 entries. The list is reissued each quarter and included with the data base documentation.

To the extent possible, the original vendors for power plant equipment or services are indicated in the WEPP data base irrespective of whether the companies exist today with that nomenclature. In some cases, predecessor companies are indicated in the List of Abbreviations. The type of service or equipment supplier (such as EPC, boiler supplier, hydro turbine supplier, IC packager, and so on) and country of origin is frequently included in the abbreviation description.

There are numerous instances where the original equipment manufacturer (OEM) is not the actual equipment supplier *per se*, for example where diesel or gas engines and gas turbines are packaged by a third party. This more often tends to be the case with smaller machines. If possible, OEM is indicated and, if not, the packager is shown. If both companies have been identified, a compound abbreviation may be entered.

Another complication is the fact that many large power generation components are manufactured by a consortium of companies. In an analogous situation, there are often multiple engineering and construction contractors working on power plant projects. In both cases, complicated abbreviations may be required to identify the major participants. Note that the actual proportion of material or other resources supplied to a particular project cannot be estimated from any data in the WEPP, nor are all major participants necessarily indicated in the abbreviations.

Finally, WEPP abbreviations may change over time. This is usually done when new information becomes available, but existing abbreviations can also be changed to reflect common usage (company acronyms, for example), or to reduce confusion between similar company names. Regional subsidiaries of multinational companies are generally not given their own abbreviation, however predecessor companies that may have been acquired and subsequently rolled up to the parent company may still be listed as originally designated.

MODEL NUMBERS

The WEPP data base has two fields for boiler and prime mover details, BOILTYPE and TURBTYPE. As with many other WEPP fields, coding conventions have evolved over time in order to supply more specific information to users.

Initially, BOILTYPE was used to show steam-electric firing configuration for conventional boilers, essentially the orientation and arrangements of the burners, the presence of HRSGs for CCGT plant, or the type of nuclear reactor in use. In many instances, this is still the case. Over time, different data became available, particularly from countries with steam generators supplied from Russia, and in these cases boiler model numbers were entered in lieu of firing configuration. For reactors, BOILTYPE showed PWR or BWR and other generic codes. In recent years, more specific data has been entered reflecting either advanced reactor technologies (EPR or AP1000 for example) or new series development as in the Chinese CPR-1000 standardized design.

TURBTYPE was designed to track engine and turbine information. Initially, this included model numbers for gas turbines and IC engines, type of turbine and turbine orientation for hydraulic turbines, and details about stages and blading for steam turbines. As wind turbines became more common, the field was then used for WTG model and/or size. For other technologies, such as photovoltaic or fuel cell power plants, TURBTYPE was again used for descriptive data. Over the last 60+ years, thousands of engine and turbine model numbers have been used in the power industry, and these are not necessarily well standardized, either by suppliers or in the WEPP.

SMALL PLANTS AND DISTRIBUTED GENERATION

For much of its existence, the development of the electric power business has been characterized by the steadily increasing size of deployed generating units, a process continuing to this day with wind turbine generators, solar power plants, and more esoteric renewable power generators such as wave generators. In part, this is due to the increasing manufacturing and engineering capability of the industry and in part to perceived economies of scale in power plant construction and operation. Nonetheless, from the beginning of large-scale deployment of new plants and through to the present day, tens of thousands of small thermal and hydroelectric power generators have also been built, particularly in remote locations or for specific industrial or commercial applications. These small facilities are now often termed distributed generation (DG).

Compilation of DG plant data is complicated and time consuming due to their great number and diverse ownership. From the beginning, the WEPP was designed to include information on power plants of any size, but it must be admitted that the true scope of the research for small plants was incompletely appreciated in the early years. The result is that while the data base has a very large number of small units – nearly half the records are for facilities of 5 MW or less – there is often no way to say what coverage this represents since there is no more complete listing extant.

The expansion and refinement of small plant data in the WEPP is undertaken on a time-available basis. As a general matter, the WEPP commercial customer base is more interested in larger plants, since these facilities spend more in absolute terms on fuel, equipment, and services. That said, it is also true that, in aggregate, small plants are of significant commercial importance, because of the original investment, continued operational expenditures, the value of their power production in local electrification, and their use of non-conventional fuels that may be available in limited quantities.

Another important point is that small power plants are easier to buy and sell due to the overall level of investment required. This has given rise to active secondary equipment markets in many countries.

Overall, small-plant data in the data base tend to be more complete where they are of more significance, *i.e.*, in smaller countries lacking well-developed centralized power systems.

In very large economies, such as those in most OECD countries, there are thousands of installed gensets that are not listed in the WEPP. It is impossible to give any meaningful estimate of their number or capacity.

CHP AND COGENERATION

Combined-heat-and-power (CHP) and cogeneration power plants have been built in large numbers around the world. (These terms are essentially synonymous in common usage and CHP is used hereafter.) CHP facilities are difficult to accurately portray in the WEPP Data Base. In part, this has to do with complications associated with the characterization of the fuels used in CHP plants and in part due to complex engineering and energy flow processes associated with CHP applications.

The CHP concept revolves around the utilization of recaptured heat energy derived from the combustion of fossil fuels that would otherwise be dissipated to the atmosphere or to condenser cooling water. This so-called waste heat can be used to generate steam and/or heat water, or used as-is for specialized drying or heating applications in industrial processes.

Oftentimes, steam is also taken off back-pressure and extraction steam turbines for use in CHP applications (UTYPE = ST/S). The steam so removed may be used directly for industrial purposes or for heating. Waste heat is also derived from the exhaust of gas turbines which is passed through an HRSG to generate steam for a steam T/G set (GT/C) or through some other type of heat exchanger for hot water production, absorption chillers, feedwater heating, desalination, or other applications (GT/D, GT/S or GT/T).

The HRSG may include supplementary firing capabilities from its own burners which can generate steam above the quantity otherwise allowed for by the GT exhaust (so called fired HRSGs, BOILTYPE = HRSG/F). In almost all instances, fired HRSGs burn natural gas in which case ALTFUEL = NONE. In some cases, specialized waste gases are used for supplementary firing, in which case ALTFUEL may be another fuel type. Until 2004 or so, the supplier of HRSGs for non-combined cycle, gas-turbine based CHP plants was not included in the WEPP data base. Subsequently, this information has been added on an as-available basis.

The use of CCGT plant for CHP applications is now more commonplace and, in 2009, new data base new coding was added to account for this usage. Gas turbines installed in CCGT/CHP plants are now coded as GT/CP and the accompanying steam sets are now coded as ST/CP. These codes are being retroactively applied. As yet, the process is not very complete.

Many smaller CHP plants use liquid-fueled or gas-fired internal combustion engines (IC, also termed reciprocating engines). In this case, there is less waste heat available and the heat is of lower quality. Heat is typically recaptured from the engine jackets using heat exchangers, which then supply hot water for district heating.

While most IC-based CHP plants in the WEPP are coded with UTYPE = IC/H, there are a small but growing number of engine-based, combined-cycle plants. These typically have large engines and small T/G sets reflecting the lower-quality waste heat available. As with gas turbines, the waste heat from engine exhaust can also be used as-is for drying and specialized heating applications. In 2009, new data base codes were also introduced for IC-based combined-cycle plants for both engines and their associated steam T/G sets.

SPECIAL FUELS AND GENERATING TECHNOLOGIES

One of the most important “special fuels” used for power and heat generation worldwide is municipal sold waste (MSW). Hundreds of millions of tons of MSW are produced each year consisting of a mix of recyclable, combustible, and inert materials. Processed or unprocessed MSW and similar industrial or commercial wastes are used as fuel for energy production in waste-to-energy (WTE) electricity and CHP plants. The WEPP data base has information for approximately 600 operating WTE generating units with electricity output. WTE plants that supply thermal energy only (as steam or hot water) are not covered in the data base. (WTE plants are also termed energy-from-waste (EFW) plants in some areas.)

WTE power plants are essentially of conventional steam-electric design, but there are some notable differences from standard plants. All new WTE plants in OECD countries must meet particularly comprehensive emission standards and so modern WTE power stations are both technologically complex and very expensive to build and operate. Typically, the back-end emissions control systems are elaborate featuring multiple particulate collectors, various types of dry or wet scrubbers for acid gas and volatile organic compounds (VOC) control, selective catalytic converters (SCR) or other NOX control devices, and, increasingly, activated carbon filtration for mercury control.

Waste fuel handling and incineration is also complicated. In many cases, one supplier will build the actual incineration equipment and a second supplier will make the steam generator (boiler). There are many different combustion methodologies used, some on an essentially experimental basis. Mass-burn plants using unprocessed MSW are by far the more common. Refuse-derived fuel (RDF) is processed MSW and offers uniformity in sizing and heat content, but, for various reasons, RDF plants have not been widely deployed. WTE plants use stoker grates, fluidized beds, fixed and rotating kilns, and other more exotic combustion techniques.

On the electric side, WTE plants tend to be small in terms of electric output and use low pressure and temperature equipment. T/G sets are of otherwise conventional design.

One other notable feature of WTE plants is essentially continuous maintenance of the combustion trains (organized in “lines”) and other plant elements due to hard usage handling corrosive materials and/or changes in legal requirements. This requires proportionately higher equipment operating investments than for almost any other type of power generation facility.

Note that some lower-grade heat sources can be utilized for electricity production using a so-called organic Rankine energy converter (ORC). Typically, these use butane or pentane as the heat-exchange medium instead of water and can be placed at such locations as natural-gas pipeline compressor stations. Such devices are also commonly used for geothermal installations. Individually, most ORC installations have small electric output, but the devices are often ganged together into larger installations.

There are approximately 200 installed geothermal electric power plants in about two dozen countries and, in aggregate, these amount to some 11 GW of installed capacity. Geothermal resources have been used for power generation for nearly a century, starting in Italy. There is also a large amount direct geothermal energy usage for district heating, space heating, spas, industrial processes, and agricultural applications but these facilities are not covered in the WEPP. Geothermal power stations have elaborate well drilling, maintenance, and piping requirements.

Geothermal power is generally cost-effective and reliable, but limited to locations with accessible reservoirs of geothermal steam or hot water that can be used for power generation. Electricity can be generated using steam piped to the surface and “flashed” through a modified steam turbine/generator set or lower-grade heat from geothermal hot water can be used in ORC applications. In the latter instance, multiple smaller turbines may be ganged together and listed *en bloc* in the data base. Few geothermal turbines are over 100 MWe in capacity.

Useful waste heat flows (*i.e.*, of sufficient volume to support power generation) may result from exothermic or other industrial processes in the metals, chemicals, cement, or other heavy industries. For electric power production in these instances, the hot gas flows are passed through an HRSG and then used to make steam for a steam T/G set as in the example above. In these cases, the only WEPP record is the steam T/G set and the actual "fuel" (that is, the actual industrial process resulting in waste heat production) is not listed.

Biogenic waste gases (BWG) are increasingly important as renewable fuels for power generation. There are three in widespread use: landfill gas, biogas, and digester gas.

Landfill gas (WEPP fuel abbreviation = LGAS, often abbreviated in the literature as LFG) was the first BWG in full commercial use in power plants designed for offsite power delivery. There are over 1,000 LFG power plants in over 50 countries in the WEPP Data Base (Sep 2009). These plants are almost always purpose-built for power generation and tend to have medium-sized gas engines in simple-cycle service, although there are some gas turbine plants and a few steam-electric plants in service as well. WEPP coverage is comprehensive.

Biogas (WEPP fuel abbreviation = BGAS) is growing in importance for power production and is widely used in Western Europe. By definition for the WEPP Data Base, biogas is produced through anaerobic digestion of agricultural waste products, purpose-grown energy crops, or food product waste. There are over 800 BGAS power plants in the WEPP Data Base (Sep 2009). These plants typically use one or two small gas engines in CHP configuration and are run by agricultural processing facilities, farms, and cooperatives of various kinds. WEPP coverage is representative.

Sewage or wastewater digester gas (WEPP fuel abbreviation = DGAS) has been used for onsite power and heat production for many years, mostly in OECD countries. By definition for the WEPP Data Base, DGAS is produced through anaerobic digestion of solids collected and processed at wastewater treatment plants (WWTP). Most of these facilities are run by water companies and municipal water and wastewater authorities. There are over 300 DGAS power plants in the WEPP Data Base (Sep 2009). These plants typically use one or two small gas engines in CHP configuration, but there are also some gas turbines and fuel cells in service with DGAS. WEPP coverage is representative.

After a long hiatus, development has been re-started on solar collector and solar tower facilities for electric power production. These plants use large fields of trough collectors or mirror fields to concentrate solar energy on receptor tubes filled with a working fluid. The high-temperature liquid is then used to generate steam in a heat exchanger unit and in turn, the steam is used in a conventional steam turbine. In most cases, supplementary firing with natural gas is used to maintain even heat flows.

Another specialized, small-scale generating technology is the steam engine. These were commonly used in the early days of electric power plant development. There are quite a number of modern steam engine power generators in service, mostly in Europe and many with non-conventional fuels. WEPP coverage of these units is sparse.

REPOWERING

Main generating equipment and ancillary systems may be reused for the development of new generating capacity at existing power plant sites. Due to the variety of different approaches in use, this activity is difficult to portray accurately in the WEPP Data Base and the unit coding scheme has evolved over time.

For thermal plants, existing steam-electric turbine generator sets may be partially or completely repowered. In partial repowering, one or more new boilers or one or more new gas turbines with one or more HRSGs are installed to drive the steam set. The resulting steam flow may also be added to steam from an existing conventional boiler. In either instance, the steam T/G set is essentially unchanged and the WEPP Data Base record for this machine is left with the existing data for year online and steam conditions.

In full repowering, the existing boiler is removed or disconnected from the rest of the steam-cycle equipment and is replaced by one or more new boilers (such as fluidized-bed equipment) or HRSGs. There are then two possibilities for the existing steam T/G set -- the machine is substantially modified during the repowering development or it remains generally as it was before. If, as is usually the case, there have been substantial mechanical or electrical modifications to the existing machine and auxiliaries, the existing T/G data record is “retired” and a new record is added. Sometimes, the data for the steam set is left as-is and the new boiler data is added to the data base record.

The names of repowered units typically include the phrase “RP” or "REPOWER."

A repowering variant is the use of gas turbine exhaust to provide combustion air or to preheat boiler feedwater for conventional steam-electric units. In these cases, most if not all the additional capacity at the plant site is from the new “topping” gas turbine (GT/T), while the benefit to the steam-electric cycle is generally in increased thermal efficiency from the reduction of parasitic electric or thermal load.

For hydroelectric plant repowering, the same general approach is used. In cases where new mechanical and/or electrical equipment is used in existing civil works, the old unit records are retired and replaced by new records. The names of the new records typically include the phrases "NEW" or "REBUILD" or the unit number may be followed by an “R” as in 1R, 2R, etc. If existing machinery is refurbished but otherwise left largely unchanged, the existing supplier data is maintained as-is and only the unit generating capacity is changed to reflect the new rating as needed.

EQUIPMENT RETROFITS

As-built main power plant equipment is frequently modernized, retrofit, or changed-out during a plant’s operating lifetime. Typical activities relevant to the WEPP Data Base include changes in primary or alternate fuels, air pollution control (APC) equipment retrofits and modernization, and modifications to plant cooling systems.

Information on such modifications and retrofits is only included in the data base when the work is actually completed and so noted in primary or secondary reference materials available to data base research staff. As a result, the data base record for a particular generating unit may not be updated for some time after new equipment has been installed and put into operation.

AIR POLLUTION CONTROL EQUIPMENT

The purchase, installation, and operation of power plant air pollution control equipment requires a significant investment of money and staff resources. Such equipment is most elaborate on coal-fired and WTE power plants, but controls are installed on most facilities using solid and liquid fuels as well as on modern gas-fired plant. About a quarter of the initial investment in new coal-fired units is routinely used for emission controls, but, in addition, some published estimates state that such equipment takes half of a power plant's annual O&M budget.

For conventional power stations, there were traditionally three main concerns, particulate matter (often called soot for oil-fired plant), sulfur dioxide, and nitrogen oxides (NOX). Over the last decade or so, mercury emissions have also become a pollutant subject to increasing stringent controls in OECD countries and WTE power plants generally must control additional, more exotic organic and inorganic compounds resulting form the consumption of municipal waste. In order to control emissions of these various pollutants, power companies have installed a bewildering array of post-combustion pollution control equipment while also investing in various in-boiler equipment modifications and more sophisticated instrumentation and control equipment. Many complicated compound WEPP data base abbreviations have been developed to attempt to account for this variability.

Insofar as the WEPP data base is concerned, there are a number of important points to keep in mind. For conventional power plants, a blank in one of the three fields used for pollution control equipment, namely PARTCTL, SO2CTL, and NOXCTL, does not indicate lack of equipment, only lack of information for use in the database. There are probably few large-scale coal, WTE, or other solid- fuel electric power plants remaining in the world with uncontrolled emissions. In a somewhat analogous situation, all larger power plants in OECD countries (and in most cases elsewhere) are required meet applicable air emission control regulations. Again, the WEPP data may or may not reflect the equipment or processes in place and/or actually in use. In addition, power plants routinely add new equipment, replace existing equipment, and/or implement site-specific modifications of one kind or another to improve control efficiency of plant operability. Data base research for these types of activities is undertaken on a time-available basis and the relevant data base fields are known to be quite incomplete.

For power plants exclusively using liquid or gaseous fuels, the baseline situation is different. Large steam-electric plants designed for heavy-fuel oil combustion or dual-fuel operation (with natural gas) were built in some numbers in the 1970s and 1980s and these mostly have particulate control equipment: some were later retrofit with FGD scrubbers and many have NOX controls. Large LNG- and gas-fired steam-electric plants built over the last 20 years or so usually have NOX controls, as do gas turbines and CCGT plant. On the other hand, older gas and oil plant may have no controls, or only rudimentary particulate collection equipment. In some cases, it is known that there is no APC equipment installed, and this is so indicated.

Oil-fired and dual-fuel diesel engines are a special case. Many of these are quite large and burn heavy fuels. By data base coding convention, the WEPP fields for particulate and SO2 control are N/A for these gensets. In fact, many have particulate filters and some are scrubbed. Many also must meet stringent requirements regarding the sulfur content of their fuel. A few data base IC plant records show specific APC equipment information.

WIND ENERGY AND PHOTOVOLTAIC PLANTS

The advent of widely-dispersed wind turbines and, especially, photovoltaic (PV) systems has become an issue for data base coverage due to the very small generating capacity of individual installations and the increasing rate of deployment worldwide. As noted elsewhere in this document, data coverage for these facilities is considered representative and not exhaustive in larger countries. Individual installations of less than 1-kW capacity are not included in the data base

Many wind turbines have been installed by individuals, municipalities, local associations, and cooperatives of various kinds. Similarly, solar PV plants are increasingly being built by commercial and industrial autproducers, municipalities and local government agencies, and individuals. In the WEPP Data Base, such wind energy and solar plants may be “rolled-up” to an operating entity that served as the original plant developer.

Residential-scale PV plants are not usually listed although larger-size housing development (housing estate) PV installations are included in aggregate where data are available. Also, blocks of PV capacity itemized by local power companies may be included where sufficient detail is available. The PV roll-ups typically have size and geographic location with design data included as available.

Note that a substantial amount of installed PV capacity is not grid-connected. Also, most PV systems used for remote telecommunications sites are not included in the WEPP Data Base.

EQUIPMENT RELOCATION

Not infrequently, IC engines and smaller gas and steam turbines are relocated to different plant sites. In some cases, these new sites are nearby, but in other cases the machinery is sent out of the country. As with repowering, this activity is difficult to track in the data base and the coding scheme has evolved gradually.

For a time, the existing unit records were moved and reattached to their new plant, thereby maintaining the Unit ID numbers (see below). This proved impractical in many instances so the general approach became to retire the existing units and create new records as needed. This also recognizes the fact that relocated machinery is often rebuilt or otherwise refurbished to “zero-hours” condition and placed under warranty, thereby becoming new equipment to all intents and purposes.

COOLING SYSTEMS

Steam-electric power plants use very large quantities of water for main condenser cooling and smaller but appreciable quantities for other plant processes. The WEPP Data Base has a single field tracking main condenser cooling (COOL). The vendor of cooling system components is not tracked in the data base.

For many large power plants, main condenser is by the so-called “once through” method where water is removed from the ocean, river, lake, etc., run through the plant and discharged, generally to the waterbody that is the original source. In a once through cooling system, little water is consumed, but flow rates are very high (and generally proportional to plant generating capacity). The List of Abbreviations has separate abbreviations for once through cooling by water type.

The other type of main condenser cooling is known as “closed-cycle” cooling. The most common closed-cycle systems use mechanical draft towers of various designs or natural draft cooling towers (also called hyperbolic towers). Here cooling water is repeatedly re-circulated so withdrawal rates are much lower, but consumption by evaporation is much higher. There are a variety of other closed-cycle cooling systems. The next most common are cooling lakes and cooling ponds.

In recent years, many power plants, particularly the steam components of combined-cycle power plants, have been installed with air-cooled condensers, essentially giant radiators. These use minimal amounts of water but exact a performance penalty. These are separately coded in the data base.

In some district-heating installations, the incorporated CHP power plant may have no cooling system at all as all heat is dissipated in the heating system piping and facilities. This type of installation has its own abbreviation.

Only steam-electric units have cooling systems listed in the WEPP Data Base. Other generating technologies need cooling as well (for example, IC engines), but this information is not recorded with a few exceptions.

A NOTE ON CHINA

For some years, the aggregate installed Chinese generating capacity value in the WEPP data base has been well short of the “official” China State Electricity Regulatory Commission (SERC) estimates released on a periodic basis.

The capacity discrepancy has been much reduced with continued research, but the remaining differences cannot be resolved at this time due to the lack of authoritative plant- and unit-level data from China other than that already compiled in the WEPP data base. This means that even if “top-down” data are available from other sources, these data are not usable in the file except for comparative purposes. Further, there does not appear to be any extant plant-and unit-level listing of all Chinese generating plants.

There are a number of factors to consider when analyzing the WEPP data for China.

1) Many large Chinese coal-fired or gas-fired plants are built in very short time periods, frequently 24 months or less. This means that new plants may already be in operation by the time an announcement of government authorization or a construction start is received by WEPP research staff.

2) It is known that not all Chinese power plants are formally authorized for construction by responsible central authorities. This makes it likely that some large power plants are not recorded for months or even years after completion.

3) English translation of Chinese power plant and power company names is difficult and time consuming and leaves many opportunities for mis-reporting, double-counting, and so on.

4) Joint power plant ownership arrangements are very common in China. These arrangements are complex and change frequently and, in a further complication, transactions are often with related companies. In general, an attempt is made to roll-up plants to the largest controlling entity.

UDI continues to work diligently to build and maintain the China power plant data set and plant- and unit-level data are constantly solicited from power companies, suppliers, and others with specialized knowledge of the Chinese power sector.

POWER PRODUCER BUSINESS TYPES AND CLASSIFICATIONS

The field BUSTYPE includes a primary business classification plus a secondary descriptor. The primary business classifications include COMM, ENERGY, FUELS, GOVT, MFG, SVCS, UTIL OTHER, and UTIL.

The secondary or functional descriptor provides additional details for the power plant operating companies. Under COMM (commercial), for example, are such establishments as greenhouses and hospitals, while MFG (manufacturing) companies include cement and building materials, pulp and paper, metals plants, textiles, and other manufacturing enterprises, ENERGY has coal, oil and gas, and so on. There are approximately 70 different primary plus secondary business combinations represented in the data base.

Note that many utilities that operate in the regulated sphere in their home markets may be IPPs in other countries.

N/A AND NOT APPLICABLE

Throughout the data base, "N/A" is used to indicate "not applicable" in alphanumeric fields. N/A fields include, for example, boiler, air pollution, and cooling system data for hydroelectric plants, particulate controls for gas turbine and combined-cycle plants, etc.

Blanks in alphanumeric fields indicate data are "not available". Blanks in numeric fields may indicate missing data or “not applicable.”

ID NUMBERS

The ID numbers on a company, location, and unit basis are data base counting fields assigned to uniquely identify each entity and do not link to any non-UDI data table or contain any other information. They are fixed once assigned.

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Appendix A - Qualitative Statement of WEPP Coverage

Fuel/Technology	***Unit Size (MW)***	***Company Type***	***WEPP Coverage***
Thermal steam-electric - fossil fuels	>=50	All	Complete except comprehensive in China
Thermal steam-electric - fossil fuels	<50	Utility, IPP	Comprehensive except representative in China
Thermal steam-electric - fossil fuels	<50	Auto/Ind	Comprehensive except adequate in China
Thermal steam-electric - waste-to-energy	All	All	Complete except comprehensive in Japan
Thermal steam-electric - biomass except bagasse	All	All	Comprehensive
Thermal steam-electric - bagasse	All	All	Comprehensive except representative in Brazil and India
Nuclear	All	All	Complete
Combined-cycle	>=50	All	Complete
Combined-cycle	<50	All	Comprehensive
Gas turbine - simple and cogen	>=15	All	Complete
Gas turbine - simple and cogen	<15	Utility, IPP	Comprehensive
Gas turbine - simple and cogen	<15	Auto/Ind	Representative
Hydroelectric - conventional	>=50	All	Complete
Hydroelectric - conventional	10-50	All	Complete except comprehensive in China
Hydroelectric - conventional	5-10	All	Comprehensive
Hydroelectric - conventional	<5	All	Representative
Hydroelectric - pumped storage	All	All	Complete
IC engines - oil and natural gas	>=20	All	Complete
IC engines - oil and natural gas	5-20	All	Comprehensive
IC engines - oil and natural gas	<5	Utility, IPP	Comprehensive
IC engines - oil and natural gas	<5	Auto/Ind	Adequate
IC engines - landfill gas	<5	All	Complete
IC engines - biogas, digester gas	<5	All	Comprehensive
Geothermal	All	All	Complete
Wind turbine - onshore	All	All	Comprehensive except representative in CN, DK, DE, and IN
Wind turbine - offshore	All	All	Complete for firm projects
Solar thermal and PV	>=5	All	Comprehensive
Solar PV	<5	All	Adequate

Notes/Description

Complete = complete or virtually complete, 95%+ of installed base
Comprehensive = considerable majority, 75%+ of installed base
Representative = probable majority or insufficient data for comparison
Adequate = insufficient data for comparison
Auto/Ind = autoproducer (captive power)/industrial

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