[[1]](#footnote-1)

Snazzy Title: Snazzy Subtitle

Tyler Davidson, Spencer Egan, Aldo Jefferson, Frank Waggoner

***Abstract*—Energy system planning and modeling is a critical step in designing power systems that operate safely and reliably for electricity consumers. The need for developing accurate plans is even more important when considering that many federal, state, and local governments have set aggressive goals for transitioning to high-penetration renewable energy systems over the next 30 years. Thus, there exists the need to create high fidelity models for power system transitions that take into account resource availability, grid stability, and system cost, amongst other factors. There are several challenges that must be addressed when considering what a 100% renewable energy system will look like. These include the intermittent nature of wind and solar power, operator regulations that require certain levels of load carrying capability, daily and seasonal changes in load, and predicted changes to the load itself over time. The following report presents a plan for a 100% renewable energy system for the City of San Diego that aims to estimate what generator capacities will be required to meet demand and what costs will be associated with such a system. It also addresses ancillary services and utility rate structures.**

***Index Terms*—Battery Storage, Capacity Expansion Modeling, Demand Response, Effective Load Carrying Capability, Electric Vehicles, Energy Modeling, Geothermal Energy, Renewable Energy, Reserve Margins, Residential Solar, Resource Adequacy, Solar Energy, Time-of-Use Utility Rates, Wind Energy.**

# I. INTRODUCTION

E

nergy systems are expensive, high impact assets that are relevant to nearly every aspect of day-to-day life. As the world continues to rely more on renewable energy resources, there will follow a growing need to build accurate system models that ensure capital investments are worthwhile and provide long-term stability and reliability to power grids. Energy systems are also multifaceted and can take many forms depending on the objective and of the system and the load they serve.

The goals of this project were to create an energy plan for a 100% renewable energy system that is able to serve a provided load at the lowest cost while maintaining grid reliability. The load provided was time-synchronous, so a secondary objective was to build a time-synchronous model that addressed these goals at each timestep for which there was load data. A scaled down load profile of San Diego Gas and Electric (SDG&E) at 5-minute intervals was the primary model input. The load profile was from 2012 so weather data from the same year was used to model weather-dependent generators like wind power and solar photovoltaics (PV). The geographic area in question was constrained to the municipal borders of the City of San Diego and land within 50 miles of those borders in any direction. Only renewable energy generation technologies were considered. A “renewable” energy source was defined as a resource that occurs naturally or would naturally replenish itself with time. This included: wind energy, solar energy, hydroelectric energy and geothermal energy. Storage technologies such as lithium ion batteries and pumped-hydro storage were also considered renewable if they were charged using a renewable technology. It was also assumed that the power system would utilize existing transmission lines with the only cost incurred being spur costs. The theoretical completion year for the energy system was 2025. It was assumed that there would be no lead times on construction and capital costs of generators would reflect projected prices for 2025. It was also assumed that if any existing generating plants were to be utilized, they would be built brand-new and therefore be subject to full capital cost. ICTs were applied to solar, wind, and geothermal generator costs based on actual federal credit rates in 2022.

To build an accurate model, data on existing conditions was gathered to determine what capacity of renewable energy was already available. Plants in operation, plants under construction, and plants in the planning phase were all considered. Solar and wind resource availability data was gathered based on the locations of existing generator plants. Models of each generator type were created to generate output profiles based on 2012 resource data. Requirements for system generators beyond serving the provided load were also considered. These included projecting changes to load based on EV and residential solar adoption, resource adequacy requirements, n-1 contingency, and reserve margins. Cost data associated with each generator and storage technology was gathered and included capital, fixed O&M, and variable O&M costs. All of the data collected was configured as inputs to a capacity expansion model. The model was run and used to determine the most cost effective total capacity mix, generation mix at each timestep, and total project costs. Finally, a utility rate structure was constructed.

# II. Existing Conditions

When you open the template, select “Page Layout” from the “View” menu in the menu bar (View | Page Layout), (these instructions assume Microsoft *Word*. Some versions may have  **Fig. 1.** This is a sample of a figure caption.

alternate ways to access the same functionalities noted here). Then, type over sections of the template or cut and paste from another document and use markup styles. The pull-down style menu is in the Formatting Toolbar at the top of your *Word* window (e.g., the style at this point in the document is “Text”). Highlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu. The style will adjust your fonts and line spacing. Do not change the font sizes or line spacing to squeeze more text into a limited number of pages.Use *italics* for emphasis; do not underline.

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## A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have already been defined in the abstract. Abbreviations such as IEEE, SI, ac, and dc do not have to be defined. Abbreviations that incorporate periods should not have spaces: write “C.N.R.S.,” not “C. N. R. S.” Do not use abbreviations in the title unless they are unavoidable (for example, “IEEE” in the title of this article).

# III. MATH

Use either the Microsoft Equation Editor or the MathType plugin, which can be obtained from <https://store.wiris.com/en/products/mathtype/download>. For help with formatting and placing equations, refer to the *IEEE Editing Math Guide* at <http://journals.ieeeauthorcenter.ieee.org/wp-content/uploads/sites/7/Editing-Mathematics.pdf> and the *IEEE MathType Tutorial for Microsoft Word Users* at <http://journals.ieeeauthorcenter.ieee.org/wp-content/uploads/sites/7/IEEE-Math-Typesetting-Guide-for-MS-Word-Users.pdf>.

TABLE I

This is a Sample of a Table Title



## A. Equations

Number equations consecutively with equation numbers in parentheses flush with the right margin of the column, as in (1). First use the equation editor to create the equation. Then

select the “Equation” markup style. Press the tab key and write the equation number in parentheses. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Use parentheses to avoid ambiguities in denominators. Punctuate equations when they are part of a sentence, as in

*Bp* + *H*2 = 40. (1)

Be sure that the symbols in your equation have been defined before the equation appears or immediately following. Italicize symbols (*T* might refer to temperature, but T is the unit tesla). When referring to an equation or formula, use simply “(1),” not “Eq. (1)” or “equation (1),” except at the beginning of a sentence: “Equation (1) is ... .”

# IV. Guidelines for Graphics Preparation and Submission

## A. Types of Graphics

The following list outlines the different types of graphics published in IEEE journals. They are categorized based on their construction, and use of color / shades of gray:

* 1. **Color/Grayscale Figures**  
     Figures that are meant to appear in color, or shades of black/gray. Such figures may include photographs,   
     illustrations, multicolor graphs, and flowcharts.
  2. **Line Art Figures**  
     Figures that are composed of only black lines and shapes. These figures should have no shades or half-tones of gray, only black and white.
  3. **Tables**  
     Data charts which are typically black and white, but sometimes include color.

## B. Multipart Figures

These are figures compiled of more than one sub-figure presented side-by-side or stacked. If a multipart figure is made up of multiple figure types (one part is line art, and another is grayscale or color), the figure should meet the stricter guidelines.

## C. File Formats for Graphics

Format and save your graphics using a suitable graphics processing program that will allow you to create the images as PostScript (PS), Encapsulated PostScript (.EPS), Tagged Image File Format (.TIFF), Portable Document Format (.PDF), JPEG, or Portable Network Graphics (.PNG). These programs can re-size them and adjust the resolution settings. If you created your source files in one of the following programs you will be able to submit the graphics without converting to a PS, EPS, TIFF, PDF, or PNG file: Microsoft Word, Microsoft PowerPoint, or Microsoft Excel. Though it is not required, it is strongly recommended that these files be saved in PDF format rather than DOC, XLS, or PPT. Doing so will protect your figures from common font and arrow stroke issues that occur when working on the files across multiple platforms. When submitting your final files, your graphics should all be submitted individually in one of these formats along with the manuscript.

## D. Sizing of Graphics

Most charts, graphs, and tables are one column wide (3.5 inches / 88 mm / 21 picas) or page wide (7.16 inches / 181 millimeters / 43 picas). The maximum depth a graphic can be is 8.5 inches (216 millimeters / 54 picas). When choosing the depth of a graphic, please allow space for a caption. Figures can be sized between column and page widths if the author chooses, however, it is recommended that figures not be sized less than column width unless when necessary.

The final printed size of author photographs is exactly   
1 in wide by 1.25 in tall (25.4 mm x 31.75 mm / 6 picas x 7.5 picas). Author photos printed in editorials measure 1.59 in wide by 2 in tall (40 mm x 50 mm / 9.5 picas x 12 picas).

## E. Resolution

The proper resolution of your figures will depend on the type of figure it is as defined in the “Types of Figures” section. Author photographs, color, and grayscale figures should be at least 300dpi. Line art, including tables should be a minimum of 600dpi.

## F. Vector Art

In order to preserve the figures’ integrity across multiple computer platforms, we accept files in the following formats: .EPS/.PDF/.PS. All fonts must be embedded or text converted to outlines in order to achieve the best-quality results.

## G. Color Space

The term “color space” refers to the entire sum of colors that can be represented within the said medium. For our purposes, the three main color spaces are grayscale, RGB (red/green/blue), and CMYK (cyan/magenta/yellow/black). RGB is generally used with on-screen graphics, whereas CMYK is used for printing purposes.

All color figures should be generated in RGB or CMYK color space. Grayscale images should be submitted in grayscale color space. Line art may be provided in grayscale OR bitmap colorspace. Note that “bitmap colorspace” and “bitmap file format” are not the same thing. When bitmap color space is selected, .TIF/.TIFF/.PNG are the recommended file formats.

## H. Accepted Fonts Within Figures

When preparing your graphics, IEEE suggests that you use one of the following Open Type fonts: Times New Roman, Helvetica, Arial, Cambria, or Symbol. If you are supplying EPS, PS, or PDF files, all fonts must be embedded. Some fonts may only be native to your operating system; without the fonts embedded, parts of the graphic may be distorted or missing.

A safe option when finalizing your figures is to strip out the fonts before you save the files, creating “outline” type. This converts fonts to artwork which will appear uniformly on any screen.

## I. Using Labels Within Figures

1. **Figure Axis Labels**
   1. Figure axis labels are often a source of confusion. Use words rather than symbols. As an example, write the quantity “Magnetization” or “Magnetization *M*,” not just “*M*.” Put units in parentheses. Do not label axes only with units. For example, write “Magnetization (A/m)” or “Magnetization (Am−1),” not just “A/m.” Do not label axes with a ratio of quantities and units. For example, write “Temperature (K),” not “Temperature/K.”
   2. Multipliers can be especially confusing. Write “Magnetization (kA/m)” or “Magnetization (103 A/m).” Do not write “Magnetization (A/m) × 1000” because the reader would not know whether the top axis label means 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8- to 10-point type.
2. **Subfigure Labels in Multipart Figures and Tables**

Multipart figures should be combined and labeled before final submission. Labels should appear centered below each subfigure in 8-point Times New Roman font in the format of (a) (b) (c).

## J. Referencing a Figure or Table Within Your Article

When referencing your figures and tables within your article, use the abbreviation “Fig.” even at the beginning of a sentence. Do not abbreviate “Table.” Tables should be numbered with Roman numerals.

## K. Submitting Your Graphics

Because IEEE will do the final formatting of your article, all figures, figure captions, and tables can be placed at the end of your article. However, if you do place your figures within the article, they should be placed at the top of the page, closest to the first mention in the text. Figures should be submitted as individual files, separate from the manuscript in one of the file formats listed above. Place figure captions below the figures; place table headings above the tables. Do not include captions as part of the figures, or put them in “text boxes” linked to the figures. Also, do not place borders around the outside of your figures.

## L. Color Processing / Printing in IEEE Transactions, Journals, and Letters

All IEEE Transactions, Journals, and Letters allow an author to publish color figures on IEEE *Xplore* at no charge, and automatically convert them to grayscale for print versions. In most journals, figures and tables may alternatively be printed in color if an author chooses to do so. Please note that this service comes at an extra expense to the author. If you intend to have print color graphics, you will have the opportunity to indicate this in the Author Gateway and will be contacted by PubOps to confirm the charges.

# V. Conclusion

## A conclusion section is not required. Although a conclusion may review the main points of the article, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes, if needed, appear before the acknowledgment.

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The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ... .” In most cases, sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page, not here.

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References need not be cited in text. When they are, they appear on the line, in square brackets, inside the punctuation. Multiple references are each numbered with separate brackets. When citing a section in a book, please give the relevant page numbers. In text, refer simply to the reference number. Do not use “Ref.” or “reference” except at the beginning of a sentence: “Reference [3] shows ... .” Please do not use automatic endnotes in *Word*, rather, type the reference list at the end of the paper using the “References” style.

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## B. Footnotes

Number footnotes separately in superscripts (Insert | Footnote).[[2]](#footnote-2) Place the actual footnote at the bottom of the column in which it is cited; do not put footnotes in the reference list (endnotes). Use letters for table footnotes (see Table I).

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References

*Basic format for periodicals:*

J. K. Author, “Name of paper,” *Abbrev. Title of Periodical*, vol. x, no. x, pp. xxx-xxx, Abbrev. Month, year, doi: 10.1109.XXX.1234567.

*Periodicals using article numbers:*

J. K. Author, “Name of paper,” *Abbrev. Title of Periodical*, vol. x, no. x, Abbrev. Month, year, Art. no. xxxxx, doi: 10.1109.XXX.1234567.

*Examples:*

# J. U. Duncombe, “Infrared navigation—Part I: An assessment of feasibility,” *IEEE Trans. Electron Devices*, vol. ED-11, no. 1, pp. 34–39, Jan. 1959, doi: 10.1109/TED.2016.2628402.

1. E. P. Wigner, “Theory of traveling-wave optical laser,” *Phys. Rev*., vol. 134, pp. A635–A646, Dec. 1965.
2. P. Kopyt *et al., “*Electric properties of graphene-based conductive layers from DC up to terahertz range,” *IEEE THz Sci. Technol.,* to be published, doi: 10.1109/TTHZ.2016.2544142. *(Note: If a paper is still to be published, but is available in early access, please follow ref [5]).)*
3. R. Fardel, M. Nagel, F. Nuesch, T. Lippert, and A. Wokaun, “Fabrication of organic light emitting diode pixels by laser-assisted forward transfer,” *Appl. Phys. Lett.*, vol. 91, no. 6, Aug. 2007, Art. no. 061103.
4. D. Comite and N. Pierdicca, "Decorrelation of the near-specular land scattering in bistatic radar systems," *IEEE Trans. Geosci. Remote Sens.*, early access, doi: 10.1109/TGRS.2021.3072864. (*Note: This format is used for articles in early access. The doi must be included.)*
5. H. V. Habi and H. Messer, "Recurrent neural network for rain estimation using commercial microwave links," *IEEE Trans. Geosci. Remote Sens.*, vol. 59, no. 5, pp. 3672-3681, May 2021. [Online]. Available: https://ieeexplore.ieee.org/document/9153027

*Basic format for books:*

J. K. Author, “Title of chapter in the book,” in *Title of Published Book, x*th ed. City of Publisher, (only U.S. State), Country: Abbrev. of Publisher, year, ch. x, sec. *x*, pp. xxx–xxx*.*

*Examples:*

1. G. O. Young, “Synthetic structure of industrial plastics,” in *Plastics,* 2nd ed., vol. 3, J. Peters, Ed. New York, NY, USA: McGraw-Hill, 1964, pp. 15–64.
2. W.-K. Chen, *Linear Networks and Systems.* Belmont, CA, USA: Wadsworth, 1993, pp. 123–135.
3. Philip B. Kurland and Ralph Lerner, eds., *The Founders’ Constitution.* Chicago, IL, USA: Univ. of Chicago Press, 1987, Accessed on: Feb. 28, 2010, [Online]. Available: http://press-pubs.uchicago.edu/founders/

*Basic format for handbooks:*

*Name of Manual/Handbook, x* ed., Abbrev. Name of Co., City of Co., Abbrev. State, Country, year, pp. xxx-xxx.

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1. *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, USA, 1985, pp. 44–60.
2. *Motorola Semiconductor Data Manual*, Motorola Semiconductor Products Inc., Phoenix, AZ, USA, 1989.
3. R. J. Hijmans and J. van Etten, “Raster: Geographic analysis and modeling with raster data,” R Package Version 2.0-12, Jan. 12, 2012. [Online]. Available: http://CRAN.R-project.org/package=raster

*Basic format for reports:*

J. K. Author, “Title of report,” Abbrev. Name of Co., City of Co., Abbrev. State, Country, Rep. xxx, year.

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1. E. E. Reber, R. L. Michell, and C. J. Carter, “Oxygen absorption in the earth’s atmosphere,” Aerospace Corp., Los Angeles, CA, USA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.

*Basic format for conference proceedings:*

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1. D. B. Payne and J. R. Stern, “Wavelength-switched passively coupled single-mode optical network,” in *Proc. IOOC-ECOC,* Boston, MA, USA,1985,   
   pp. 585–590.
2. D. Ebehard and E. Voges, “Digital single sideband detection for interferometric sensors,” presented at the 2nd Int. Conf. Optical Fiber Sensors*,* Stuttgart, Germany, Jan. 2-5, 1984.
3. PROCESS Corporation, Boston, MA, USA. Intranets: Internet technologies deployed behind the firewall for corporate productivity. Presented at INET96 Annual Meeting. [Online]. Available: http://home.process.com/Intranets/wp2.htp

*Basic format for electronic documents (when available online):*

Issuing Organization. (year, month day). *Title*. [Type of medium]. Available: site/path/file

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1. U.S. House. 102nd Congress, 1st Session. (1991, Jan. 11). *H. Con. Res. 1, Sense of the Congress on Approval of Military Action*. [Online]. Available: LEXIS Library: GENFED File: BILLS

*Basic format for patents:*

J. K. Author, “Title of patent,” U.S. Patent *x xxx xxx*, Abbrev. Month, day, year.

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1. G. Brandli and M. Dick, “Alternating current fed power supply,” U.S. Patent 4 084 217, Nov. 4, 1978.

*Basic format**for theses (M.S.) and dissertations (Ph.D.):*

J. K. Author, “Title of thesis,” M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

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*Examples:*

1. J. O. Williams, “Narrow-band analyzer,” Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, USA, 1993.
2. N. Kawasaki, “Parametric study of thermal and chemical nonequilibrium nozzle flow,” M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

*Basic format for the most common types of unpublished references:*

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J. K. Author, “Title of paper,” unpublished.

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*Examples:*

1. A. Harrison, private communication, May 1995.
2. B. Smith, “An approach to graphs of linear forms,” 2014, *arXiv:2105.02824*.
3. A. Brahms, “Representation error for real numbers in binary computer arithmetic,” IEEE Computer Group Repository, Paper R-67-85.

*Basic formats for standards:*

a) *Title of Standard*, Standard number, date.

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1. IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.
2. Letter Symbols for Quantities, ANSI Standard Y10.5-1968.

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