

58th CIRP Conference on Manufacturing Systems

Algorithmic maximization of energy productivity to achieve net-zero emissions for production sites

Michael Frank*, Borys Ioshchikhes

*Institute for Production Management, Technology and Machine Tools (PTW), Technical University of Darmstadt, Otto-Berndt-Str. 2, 64287 Darmstadt, Germany** Corresponding author. Tel.: +49-6151-8229-643. E-mail address: m.frank@ptw.tu-darmstadt.de**Abstract**

The development of transformation concepts aimed at achieving net-zero emissions for production sites represents a complex planning task. In this context, mathematical optimization has been demonstrated to be an effective methodology. Current investment and deployment planning approaches neglect the economic realities of production sites by focusing solely on greenhouse gas reduction. Therefore, this article presents a mathematical optimization approach for the maximization of the energy productivity of a production site. The integration of production processes and supply systems in a unified modeling approach results in economically viable solutions. The approach is validated by its application to the ETA Research Factory.

© 2025 The Authors. Published by Elsevier B.V.

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)
Peer-review under responsibility of the scientific committee of the 55th CIRP Conference on Manufacturing System.**Keywords:** mathematical optimization; production sites; transformation concepts; energy productivity; net-zero emissions;**1. Main Text**

A study that is based on mathematical optimization is based on these elements: 1. description of the use case, motivation and estimated scenarios 2. description of the applied modelling, simulation and solution methods or heuristics 3. presentation of the study outcome 4. discussion of the study outcome and in best case derivation of clear influencing metrics of the study outcome 5. critical analysis influencing elements of the study (scenario, modelling, heuristic)

Here introduce the paper, and put a nomenclature if necessary, in a box with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 10 pt. Here follows further instructions for authors.

Nomenclature

A radius of

B position of
C further nomenclature continues down the page inside the text box

1.1. Structure

Files must be in LaTeX format only and should be formatted for direct printing, using the CRC LaTeX template provided. Figures and tables should be embedded and not supplied separately.

Please make sure that you use as much as possible normal fonts in your documents. Special fonts, such as fonts used in

the Far East (Japanese, Chinese, Korean, etc.) may cause problems during processing. To avoid unnecessary errors you are strongly advised to use the ‘spellchecker’ function of TeX Editor. Follow this order when typing manuscripts: Title, Authors, Affiliations, Abstract, Keywords, Main text (including figures and tables), Acknowledgements, References, Appendix. Collate acknowledgements in a separate section at the end of the article and do not include them on the title page, as a footnote to the title or otherwise.

Bulleted lists may be included and should look like this:

- First point
- Second point
- And so on

Ensure that you return to the ‘Els-body-text’ style, the style that you will mainly be using for large blocks of text, when you have completed your bulleted list.

Please do not alter the formatting and style layouts which have been set up in this template document. As indicated in the template, papers should be prepared in single column format suitable for direct printing onto paper with trim size 192 × 262 mm. Do not number pages on the front, as page numbers will be added separately for the preprints and the Proceedings. Leave a line clear between paragraphs. All the required style templates are provided in the file “LaTeX Template” with the appropriate name supplied, e.g. choose 1. Els1st-order-head for your first order heading text, els-abstract-text for the abstract text etc.

1.2. Tables

All tables should be numbered with Arabic numerals. Every table should have a caption. Headings should be placed above tables, left justified. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately. Below is an example which the authors may find useful.

Table 1. An example of a table.

An example of a column heading	Column A (<i>t</i>)	Column B (<i>t</i>)
And an entry	1	2
And another entry	3	4
And another entry	5	6

1.3. Construction of references

References must be listed at the end of the paper. Do not begin them on a new page unless this is absolutely necessary. Authors should ensure that every reference in the text appears in the list of references and vice versa. Indicate references by [1] or in the text.

Some examples of how your references should be listed are given at the end of this template in the ‘References’ section,

which will allow you to assemble your reference list according to the correct format and font size.

Reference generation by using bibliography style commands for LaTeX template only.

The author may use “elsarticle-num.bst” as per the style required in document. The sample bib file could be referred. If the author may using bibstyle for providing references author must comment the bibliography section in TeX file, Bibtex will generate the reference automatically.

If the author may not able to view the references in output same could be done by copying the bibliography section from “filename.bbl” file and paste in TeX file.

1.4. Section headings

Section headings should be left justified, bold, with the first letter capitalized and numbered consecutively, starting with the Introduction. Sub-section headings should be in capital and lower-case italic letters, numbered 1.1, 1.2, etc, and left justified, with second and subsequent lines indented. All headings should have a minimum of two text lines after them before a page or column break. Ensure the text area is not blank except for the last page.

1.5. General guidelines for the preparation of your text

Avoid hyphenation at the end of a line. Symbols denoting vectors and matrices should be indicated in bold type. Scalar variable names should normally be expressed using italics. Weights and measures should be expressed in SI units. All non-standard abbreviations or symbols must be defined when first mentioned, or a glossary provided.

1.6. File naming and delivery

Please title your files in this order ‘procedia acronym_conference acronym_authorslastname’. Submit both the source file and the PDF to the Guest Editor.

Artwork filenames should comply with the syntax “aabbabbbb.ccc”, where:

- a = artwork component type
 - b = manuscript reference code
 - c = standard file extension
- Component types:
- gr = figure
 - pl = plate
 - sc = scheme
 - fx = fixed graphic

1.7. Footnotes

Footnotes should be avoided if possible. Necessary footnotes should be denoted in the text by consecutive superscript letters¹.

¹ Footnote text.

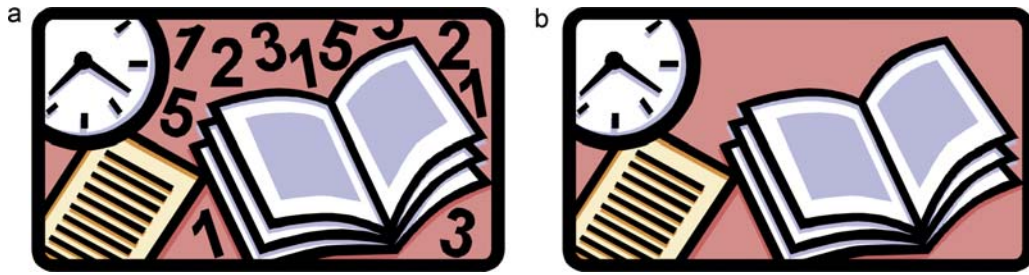


Fig. 1. (a) first picture; (b) second picture.

The footnotes should be typed single spaced, and in smaller type size (8 pt), at the foot of the page in which they are mentioned, and separated from the main text by a one line space extending at the foot of the column. The ‘Els-footnote’ style is available in the “TeX Template” for the text of the footnote.

Please do not change the margins of the template as this can result in the footnote falling outside printing range.

2. Illustrations

All figures should be numbered with Arabic numerals (1,2,3,...). Every figure should have a caption. All photographs, schemas, graphs and diagrams are to be referred to as figures. Line drawings should be good quality scans or true electronic output. Low-quality scans are not acceptable. Figures must be embedded into the text and not supplied separately. In MS word input the figures must be properly coded. Preferred format of figures are PNG, JPEG, GIF etc. Lettering and symbols should be clearly defined either in the caption or in a legend provided as part of the figure. Figures should be placed at the top or bottom of a page wherever possible, as close as possible to the first reference to them in the paper. Please ensure that all the figures are of 300 DPI resolutions as this will facilitate good output.

The figure number and caption should be typed below the illustration in 8 pt and left justified [*Note:* one-line captions of length less than column width (or full typesetting width or oblong) centered]. For more guidelines and information to help you submit high quality artwork please visit: <http://www.elsevier.com/artworkinstructions> Artwork has no text along the side of it in the main body of the text. However, if two images fit next to each other, these may be placed next to each other to save space. For example, see Fig. 1.

3. Equations

Equations and formulae should be typed in MathType, and numbered consecutively with Arabic numerals in parentheses on the right hand side of the page (if referred to explicitly in the

text). They should also be separated from the surrounding text by one space

$$X_r = \dot{Q}_{rad}'' / (\dot{Q}_{rad}'' + \dot{Q}_{conv}'')$$

$$\rho = \frac{\vec{E}}{J_c(T = \text{const.}) \cdot \left(P \cdot \left(\frac{\vec{E}}{E_c} \right)^m + (1 - P) \right)} \quad (1)$$

4. Online license transfer

All authors are required to complete the Procedia exclusive license transfer agreement before the article can be published, which they can do online. This transfer agreement enables Elsevier to protect the copyrighted material for the authors, but does not relinquish the authors’ proprietary rights. The copyright transfer covers the exclusive rights to reproduce and distribute the article, including reprints, photographic reproductions, microfilm or any other reproductions of similar nature and translations. Authors are responsible for obtaining from the copyright holder, the permission to reproduce any figures for which copyright exists.

Acknowledgements

Acknowledgements and Reference heading should be left justified, bold, with the first letter capitalized but have no numbers. Text below continues as normal.

Appendix A. An example appendix

Authors including an appendix section should do so before References section. Multiple appendices should all have headings in the style used above. They will automatically be ordered A, B, C etc.

A.1. Example of a sub-heading within an appendix

There is also the option to include a subheading within the Appendix if you wish.

References

- [1] Gilbert Fridgen, Robert Keller, Marc-Fabian Körner, Michael Schöpf, [A holistic view on sector coupling](#), Energy Policy 147 (2020) 111913. doi:10.1016/j.enpol.2020.111913.
URL <https://www.sciencedirect.com/science/article/pii/S0301421520306248>