



Project on the Energy
and Environmental Impacts
of the Digital Economy

Investigating the Energy and Environmental Implications of Artificial Intelligence Applications in the Chemical Manufacturing Industry

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What problem(s) did your research address?

- Problem(s)

The lack of quantitative understandings of potential impacts, especially energy and environmental impacts, of AI applications in the chemical manufacturing industry.

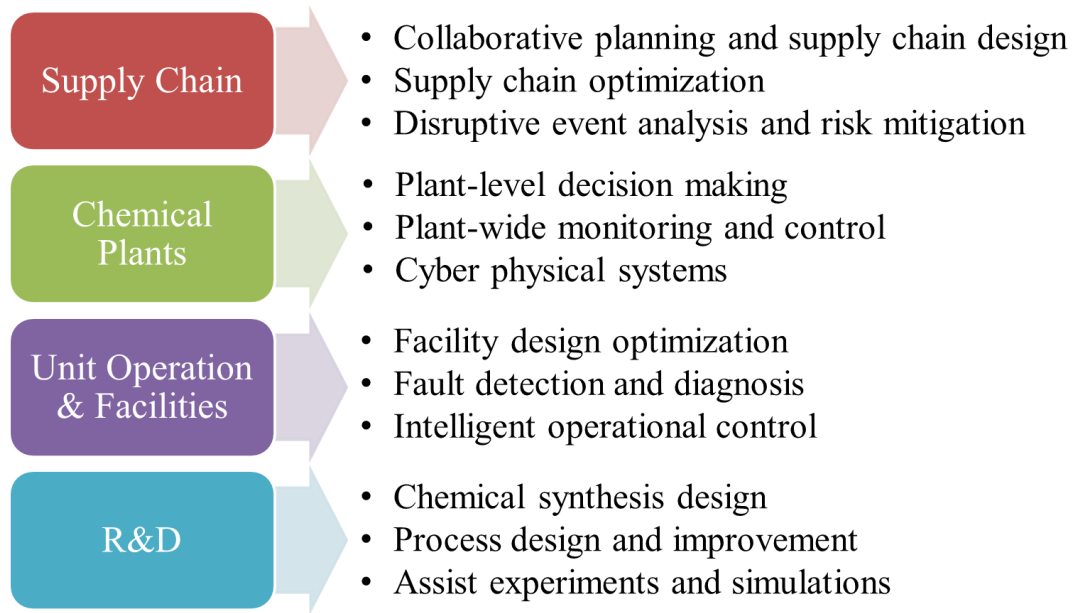
- Why is this problem(s) important?

Such knowledge and understandings are critical for

- **technology investment and adoption**
- **individual or industry-wide strategic planning**
- **policymaking and determining funding priority**
- **directions of future research and technology development**

Methodology

- Literature review of AI application case studies
- Characterized AI applications by the application levels and functions



Methodology

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We identified that one of the biggest challenges are to match appropriate assessment methods and performance indicators with different and complex AI applications in the chemical industry.



- Exploration and analysis of existing assessment methods
- Development of a methodology framework that can guide the selection of suitable methods and performance indicators to quantify the environmental and economic implications of AI.

Major Findings

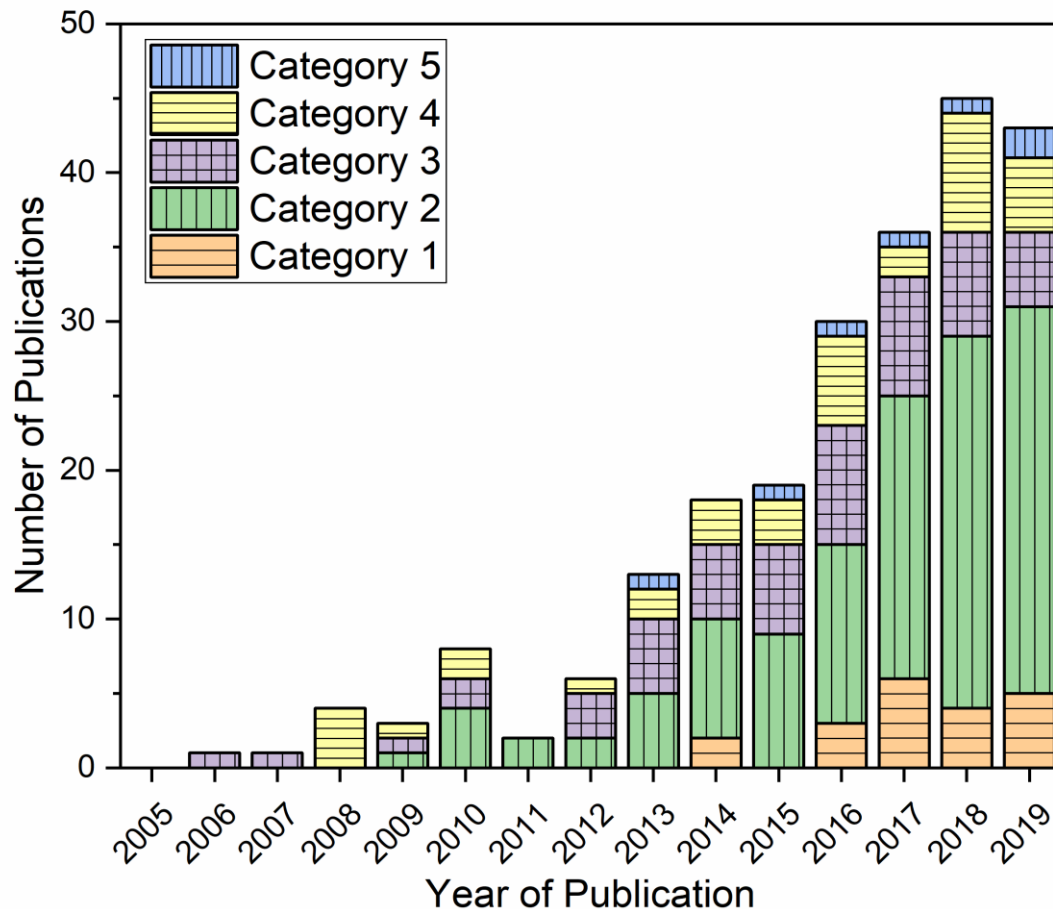
Matrix-Based Characterization of AI Applications

	Research & Development	Facilities & Unit Operation	Chemical Plants	Supply Chain
<i>Economic</i>				
- Capacity and Yields	N	2(2)	3(3)	N
- Profit Margin	N	3(3)	N	3(3)
- Direct & indirect Cost	5	9(3)	8(6)	1
<i>Energy</i>				
- Energy Efficiencies	N	6(6)	2(1)	N
- Specific Energy Consumption	N	3(3)	5(5)	N
<i>Environment</i>				
- Emission to Air/water/land	Reduce the # of experiments to decrease the emission.	3(3)	1	3(3)
- Life cycle impact categories		N	N	1
<i>Safety & Human</i>				
- Product Safety	1(1)	N	N	N
- Chemical process monitoring	N	3(2)	5(4)	N
- Risk Management	N	2(2)	5(2)	3(2)
- Individual efficiencies	1(1)	N	3(3)	1
- Simulations	N	N	N	4
<i>Time</i>				
- Chemical Product & Process Design	5(1)	N	N	N
- Experiments	3(1)	N	N	N
- Computation	2	N	N	1(1)

Note: Numbers in parenthesis indicate the number of applications that provide quantitative indicator values.

AI Applications in Emerging Area - Biofuel Production

229 articles have been reviewed for AI applications in biofuel system across its life cycle.



Category 1: prediction of biomass feedstock properties for rapid screening (n = 20)

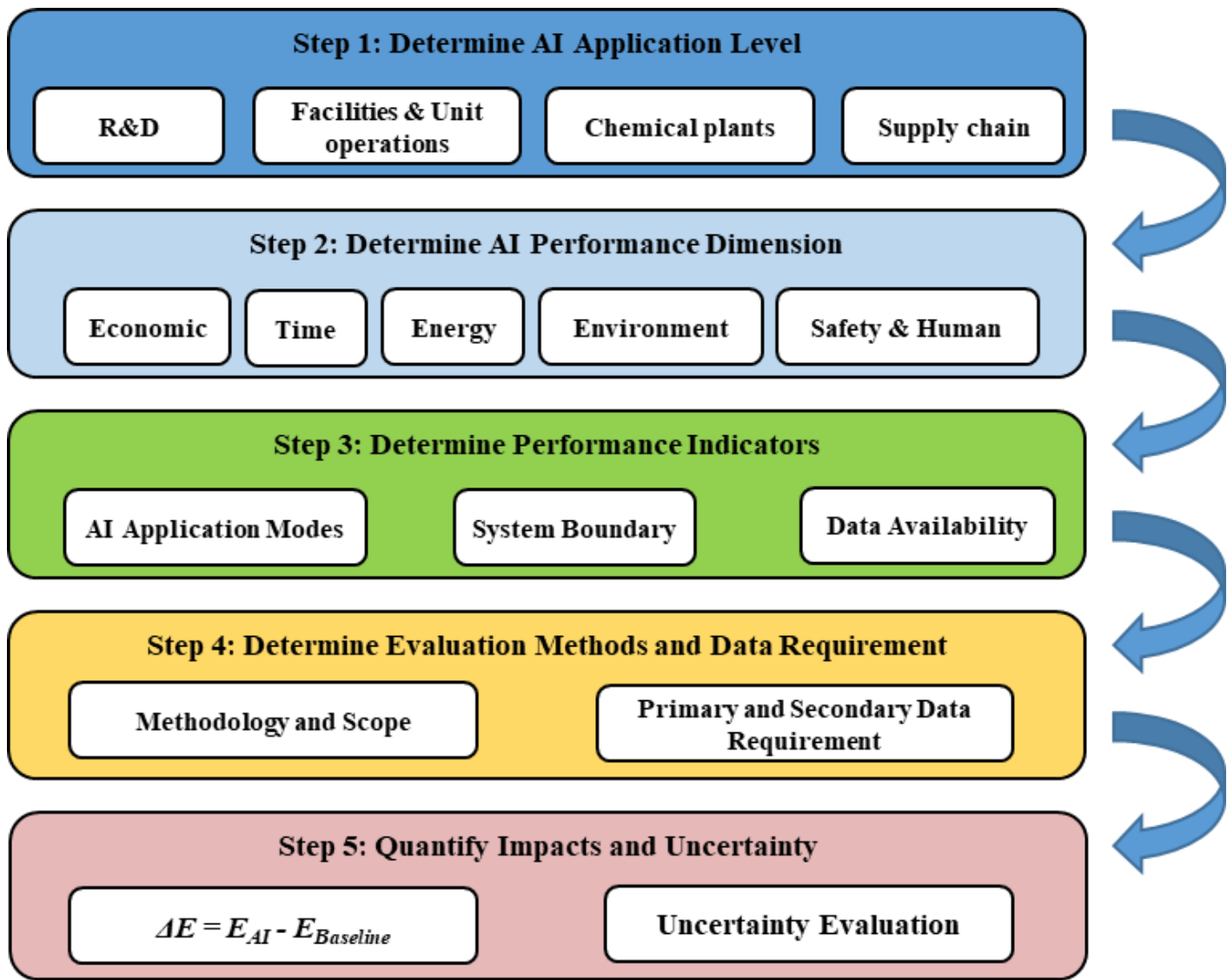
Category 2: prediction of process-based performance indicators of biomass conversion for process optimization and design (n = 113)

Category 3: prediction of biofuel properties and devices/facilities performance for the optimal utilization of bioenergy (n = 52)

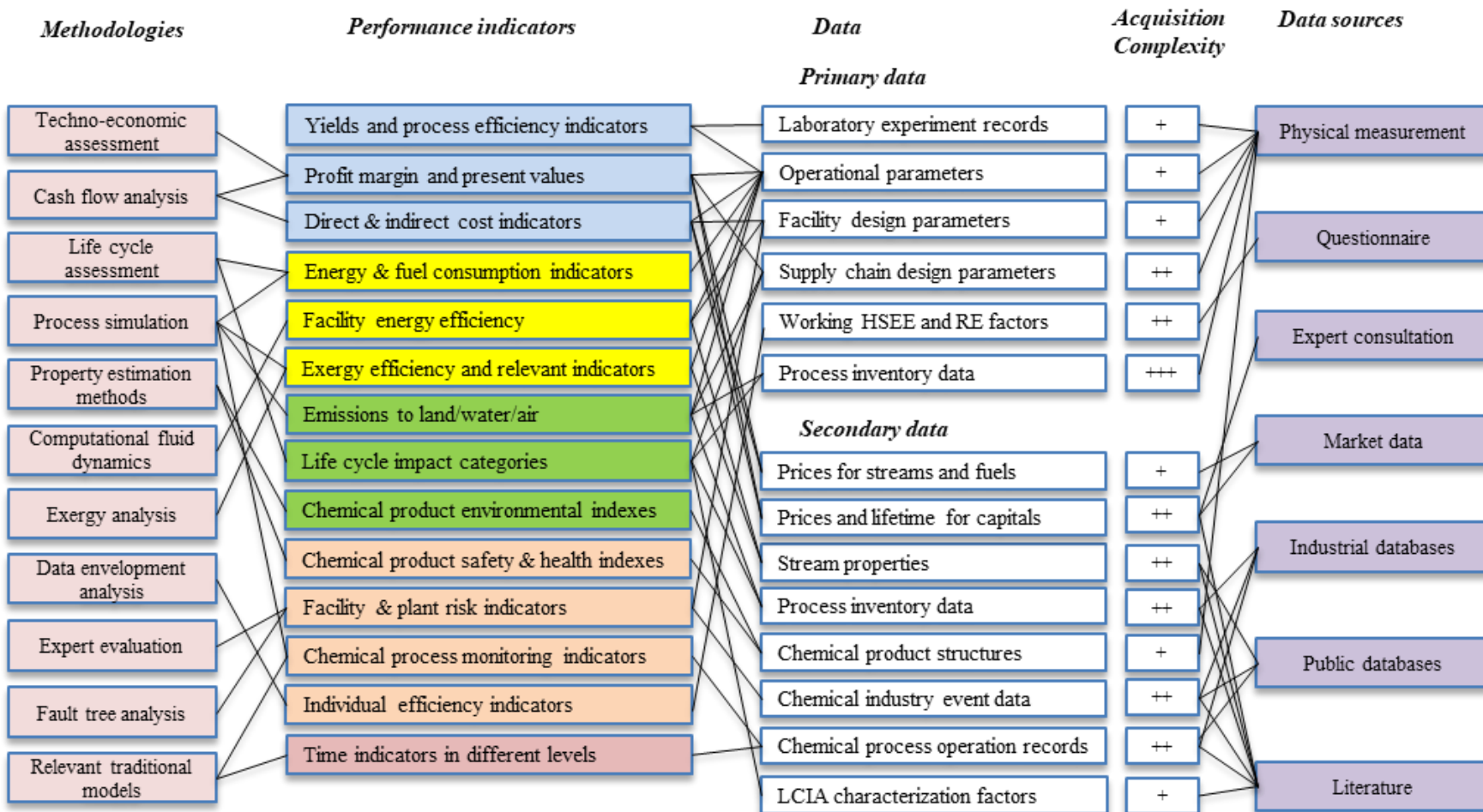
Category 4: optimization for supply chain design and planning from both technical and sustainability perspectives (n = 37)

Category 5: other novel applications of AI in bioenergy system, such as AI for emerging technologies, and AI for bioenergy sustainability assessment (n = 7)

New Methodology Framework



A Preliminary Map for Method-Performance Indicator-Data (in step 4)



Economic
 Energy
 Environment
 Safety & Human
 Time

Barriers and Surprises

- What were the major barriers you confronted?
 - A lots of publications and case studies but most of them only provide qualitative discussions without providing quantitative data of AI's impacts, especially those related to energy and environmental impacts
- What surprised you during the research?
 - A very limited number of studies mentioned about potential environmental and energy benefits of AI, most of literature focused on economic and safety benefits of implementing AI techniques in different chemical plants.
 - Quantifying the implications and potential impacts of AI is challenging. At first we thought the challenge mainly comes from data, but then we realized that a bigger challenge (that needs to be addressed first) is to identify the appropriate methods to assess such impacts and determine what data needs to be collected and analyzed.

Research Opportunities

- What would you do if you had more funding?
 - We would like to conduct a few case studies that allows for the applications of the methodology framework developed in this project to demonstrate its functionality and usefulness.
- Other knowledge gaps that should be addressed
 - What are the chemicals/processes/technologies that have large energy saving/environmental impact reduction opportunities for AI adoption?
 - Are there any unexpected consequences/risks of AI implementation?

Final observations

- ✓ Completed a review of different AI applications in the chemical industry
- ✓ Completed a review of AI applications specifically for biofuel systems (emerging research area) – manuscript under revision
- ✓ Developed a methodology framework to assist the selection of assessment methods and performance indicators to quantify the potential impacts of AI adoption in the chemical industry – manuscript under preparation

Future Research

- Case studies to demonstrate the methodology framework
- Conduct assessments for AI applications (e.g., LCA)
- Bandwidth study to identify areas with high potential