

Technology Assessment for Sustainability Performance Improvement in Metal Finishing Facilities

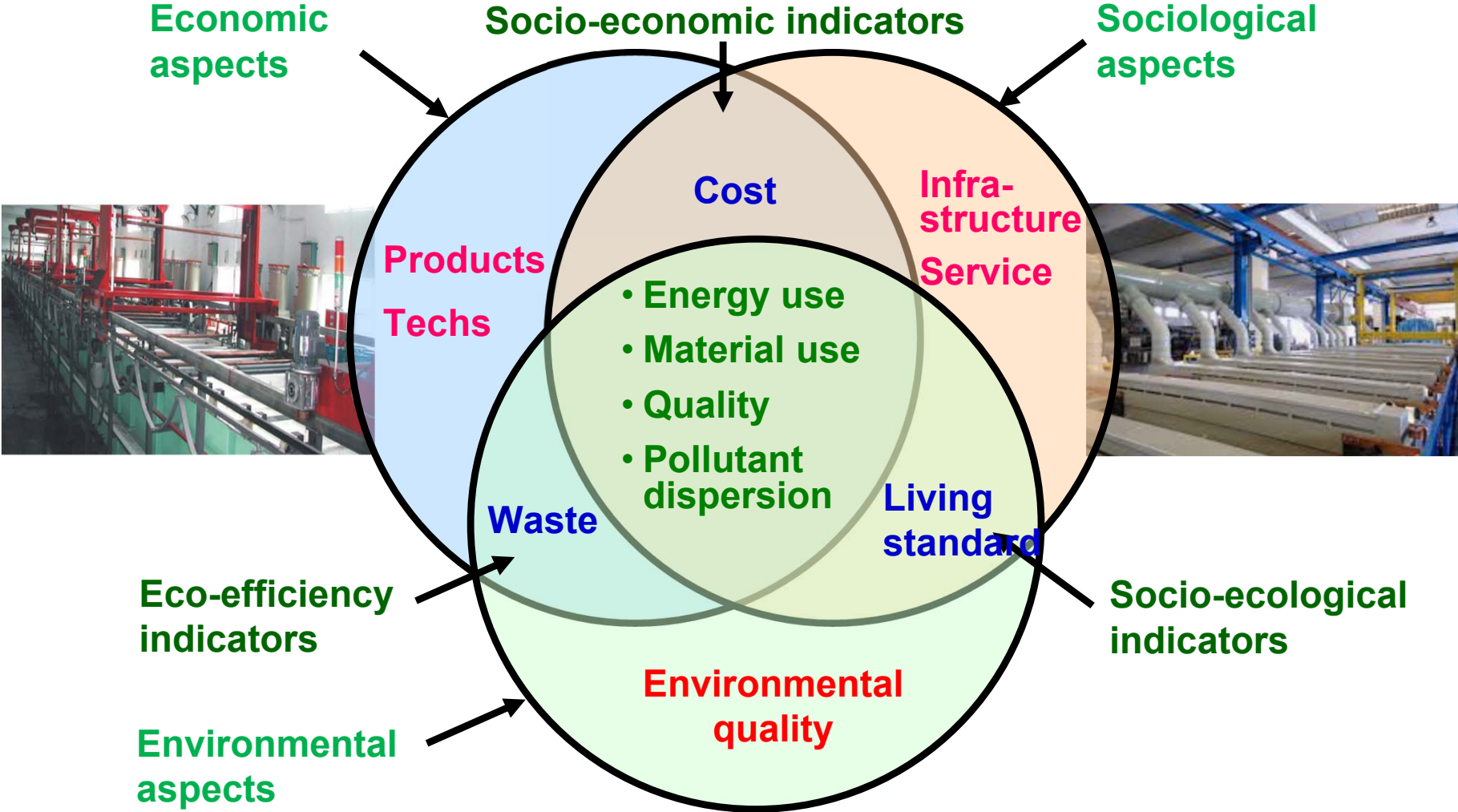
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**Session 8: Innovations for Improving Productivity
SURFIN 22 NASF Annual Meeting
Rosemont, IL, June 7-9, 2022**

Introduction

- **Manufacturing companies making sustainability a goal have achieved competitive advantage in business development.**
- **Sustainability is a key driver of innovation.**
- **Electroplating facilities need to keep up with technological advancement**
- **Technologies must be assessed in order to ensure techno-economical attractiveness, environmental clearness and social responsibility.**

Triple-Bottom-Line-Based Sustainability



Sustainability Metrics System Developed for Surface Finishing

- **A total of 53 indicators have been developed at Wayne State University**
- **Each sustainability category contains 3 or 4 subcategories.**
- **The indicators are divided into two sets.**

Sustainability Category	# of indicators in Set A	# of indicators in Set B
Economic	12	8
Environmental	12	7
Social	7	7
Total	31	22

Economic Sustainability Indicators (Set A)

Sub-category	Indicator
E-1: Profit, Value and Tax	E-1-1: Value added (\$/y)
	E-1-3: Net profit margin (%/\$)
	E-1-5: Tax paid as percent of NIBT (%)
	E-1-6: Return on average capital employed (%/y)
E-2: Investments	E-2-1: Percentage increase in capital employed (%/y)
	E-2-4: Investment for employee's education/training
	E-2-5: Investment on new technology (\$/y)
E-3: Technology Advancement	E-3-1: Production increment percentage per dollar investment on new technology (%/\$-new tech)
	E-3-3: Product quality improvement percentage per dollar investment on new technology (%/\$-new tech)
	E-3-5: Waste reduction percentage per dollar investment on new technology (%/\$-new tech)
E-4: Production and Product Quality	E-4-1: Percentage of product delivered on time (%)
	E-4-3: Product return rate after shipment (%)

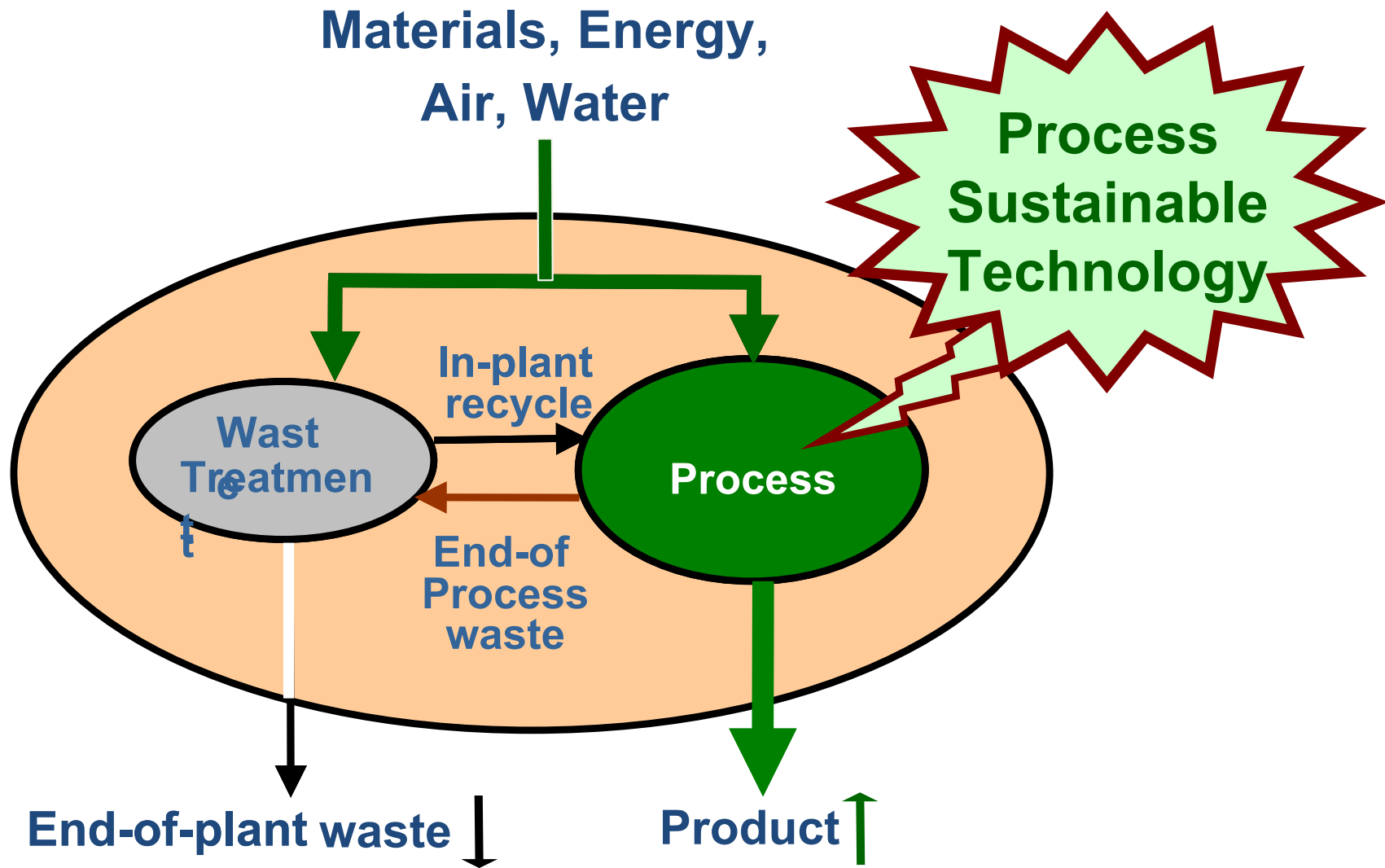
Environmental Sustainability Indicators (Set A)

Sub-category	Indicator
V-1: Materials (excluding fuel and water)	V-1-1: Chemical use in production per value added (lb/\$)
	V-1-3: Chemical use in waste treatment per value added (lb/S)
	V-1-4: Plating solution use per value added (lb/\$)
V-2: Water	V-2-1: Fresh water use in production per dollar of product sales (lb/\$)
	V-2-3 Used water reused in production before treatment (%)
V-3: Energy	V-3-1: Electricity use per value added (kW/\$)
	V-3-3: Clean energy use among all energy (%)
	V-3-5: Non-production energy among all energy consumption (%)
V-4: Waste Generation and Effluents	V-4-1: Spent solutions per value added (lb/\$)
	V-4-2: Wastewater generated in production per value added (lb/s)
	V-4-3: Wastewater treatment sludge per value added (lb/\$)
	V-4-4: Hazardous waste generated per value added (lb/\$)

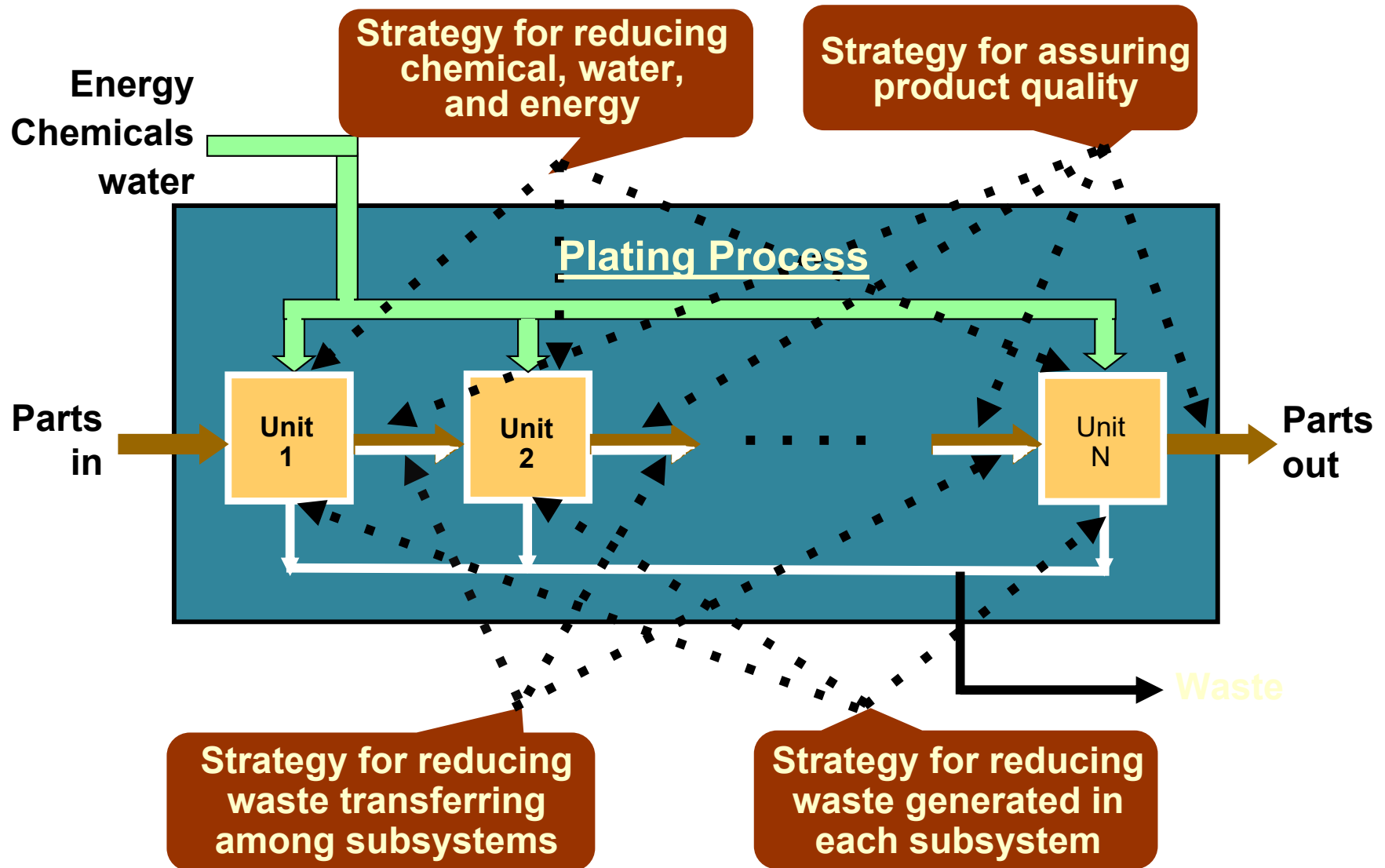
Social Sustainability Indicators (Set A)

Sub-category	Indicator
L-1: Workplace	L-1-1: Benefits as percentage of payroll expense (%)
	L-1-2: Work related re-education and/or training (%)
L-2: Safety and Health	L-2-2: Number of accidents in workplace (/y)
	L-2-3: Chemical leakage in plant (/y)
L-3: Society	L-3-3: Number of complaints from local community (/y)
	L-3-4: Number of complaints from customers (/y)
	L-3-5: Number of legal actions per value added (/y)

Technology Development Strategy



Strategic Development of Technologies



Technology Assessment Formulation

Process sustainability assessment (before tech adoption)

$$E(P) = \frac{\sum_{i=1}^{N_E} a_i E_i}{\sum_{i=1}^{N_E} a_i} \quad (1); \quad V(P) = \frac{\sum_{i=1}^{N_V} b_i V_i}{\sum_{i=1}^{N_V} b_i} \quad (2); \quad L(P) = \frac{\sum_{i=1}^{N_L} c_i L_i}{\sum_{i=1}^{N_L} c_i} \quad (3);$$

$$S(P) = \frac{\|(\alpha E(P), \beta V(P), \gamma L(P))\|}{\|(\alpha, \beta, \gamma)\|} \quad (4)$$

Technology sustainability improvement capability assessment

$$E(T) = \frac{\sum_{i=1}^{N_E} a_i E_i}{\sum_{i=1}^{N_E} a_i} \quad (5); \quad V(T) = \frac{\sum_{i=1}^{N_V} b_i V_i}{\sum_{i=1}^{N_V} b_i} \quad (6); \quad L(T) = \frac{\sum_{i=1}^{N_L} c_i L_i}{\sum_{i=1}^{N_L} c_i} \quad (7),$$

Process sustainability assessment (after tech implementaton)

$$E(T; P) = \frac{\sum_{i=1}^{N_E} a_i E_i}{\sum_{i=1}^{N_E} a_i} \quad (8); \quad V(T; P) = \frac{\sum_{i=1}^{N_V} b_i V_i}{\sum_{i=1}^{N_V} b_i} \quad (9); \quad L(T; P) = \frac{\sum_{i=1}^{N_L} c_i L_i}{\sum_{i=1}^{N_L} c_i} \quad (10),$$

$$S(T; P) = \frac{\|(\alpha E(T; P), \beta V(T; P), \gamma L(T; P))\|}{\|(\alpha, \beta, \gamma)\|} \quad (11)$$

Case Study

- **Two technologies were chosen for the improvement of electroplating facilities**
 - **T1: Chemical use reduction technology involving the addition of a new tank and an automated rinsing system**
 - **T2: Water recycling technology involving multiple recycle streams cycling water back into the process**
- **Data for the technologies was collected from previous papers**

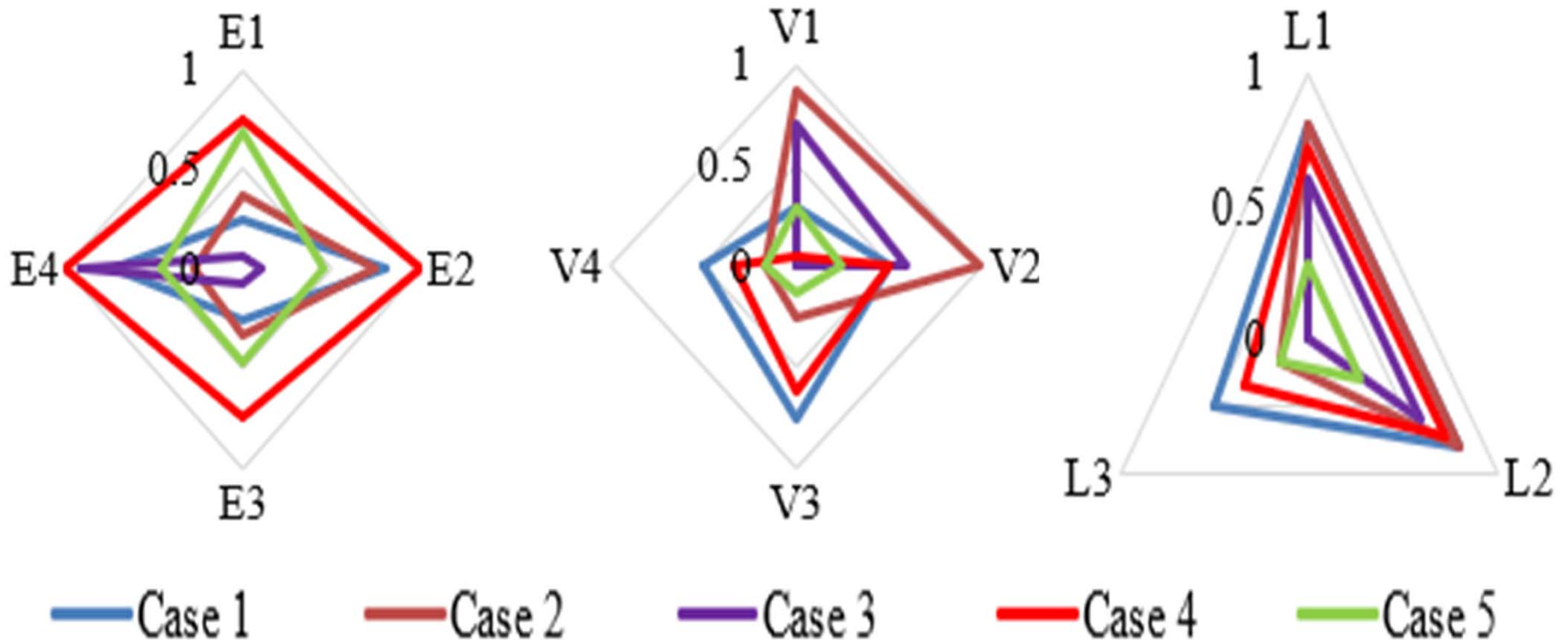
Case Study: Technology Assessment Data

Category	Indicator	Technology 1	Technology 2
Economic Sustainability	Value Added	11% Increase	8% Increase
	Net Profit Margin	5% Increase	2% Increase
	Investment on New Technology	\$47,000 Increase	\$32,000 Increase
	Product Defect Rate	N/A	N/A
Environmental Sustainability	Fresh Water Use in Production per Value Added	5% Reduction	27% Reduction
	Wastewater Generated in Production per Value Added	13% Reduction	27% Reduction
	Fraction of Water Recycled within Plant	N/A	27% Reduction
	Hazardous Waste Generated per Value Added	13% Reduction	27% Reduction
Social Sustainability	Number of Complaints from Customers	N/A	60% Reduction
	Number of Complaints from Local Community	N/A	N/A
	Human Health Burden per Value Added	7% Reduction	14% Reduction

Case Study: Technology Assessment

Sustainability indicators used for tech assessment

- **Economic: E1 – E4**
- **Environmental: V1 – V4**
- **Social: L1 – L3**

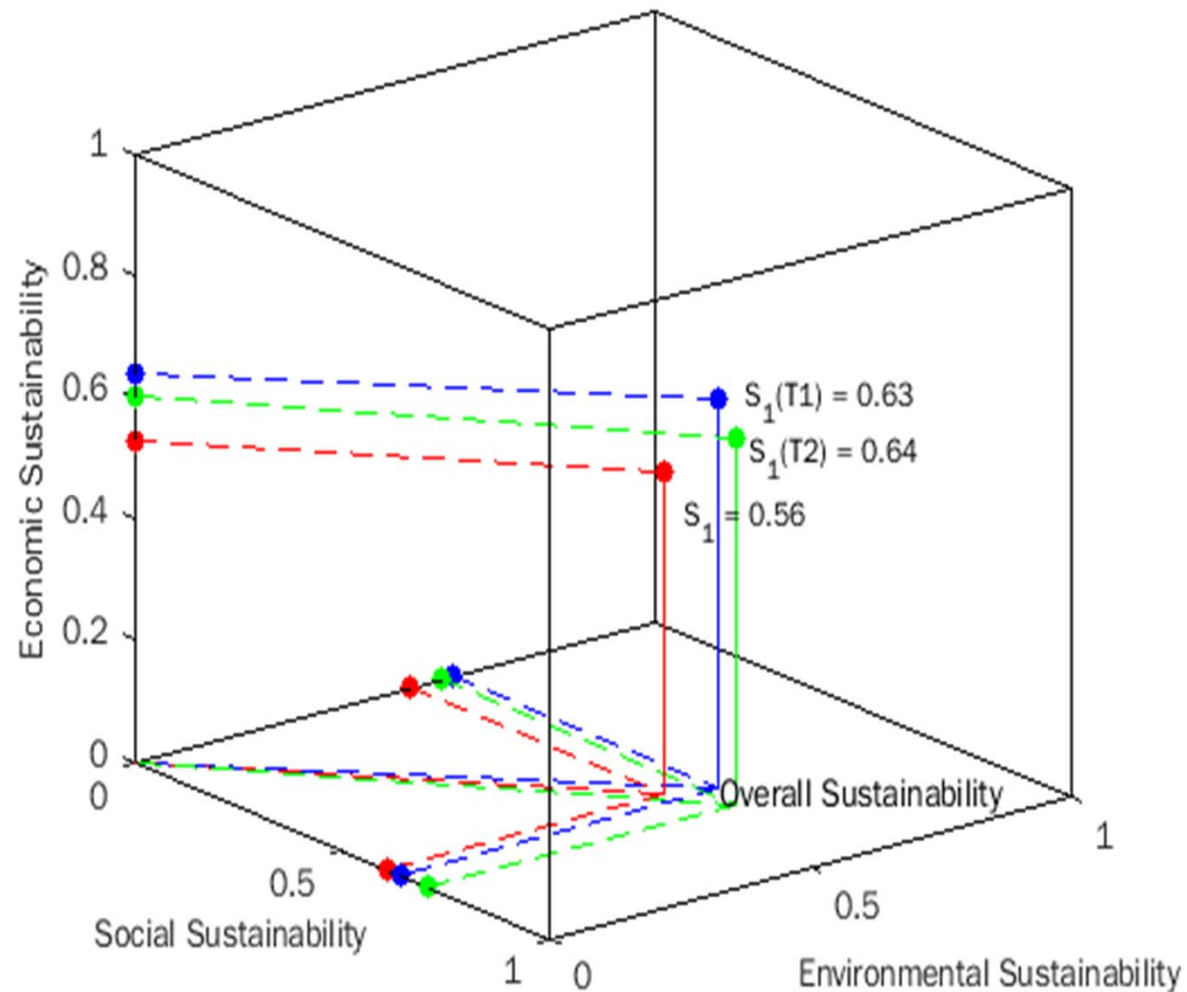


Case Study 1 – Results and Graphic Presentation

Comparison:

- **Overall Sustainability:**
0.56
- **Sustainability after implementing Tech 1:**
0.63
- **Sustainability after implementing Tech 2:**
0.64

Category	Original	Technology 1	Technology 2
Economic	0.53	0.64	0.60
Environmental	0.53	0.61	0.59
Social	0.61	0.64	0.72
Overall	0.56	0.63	0.64

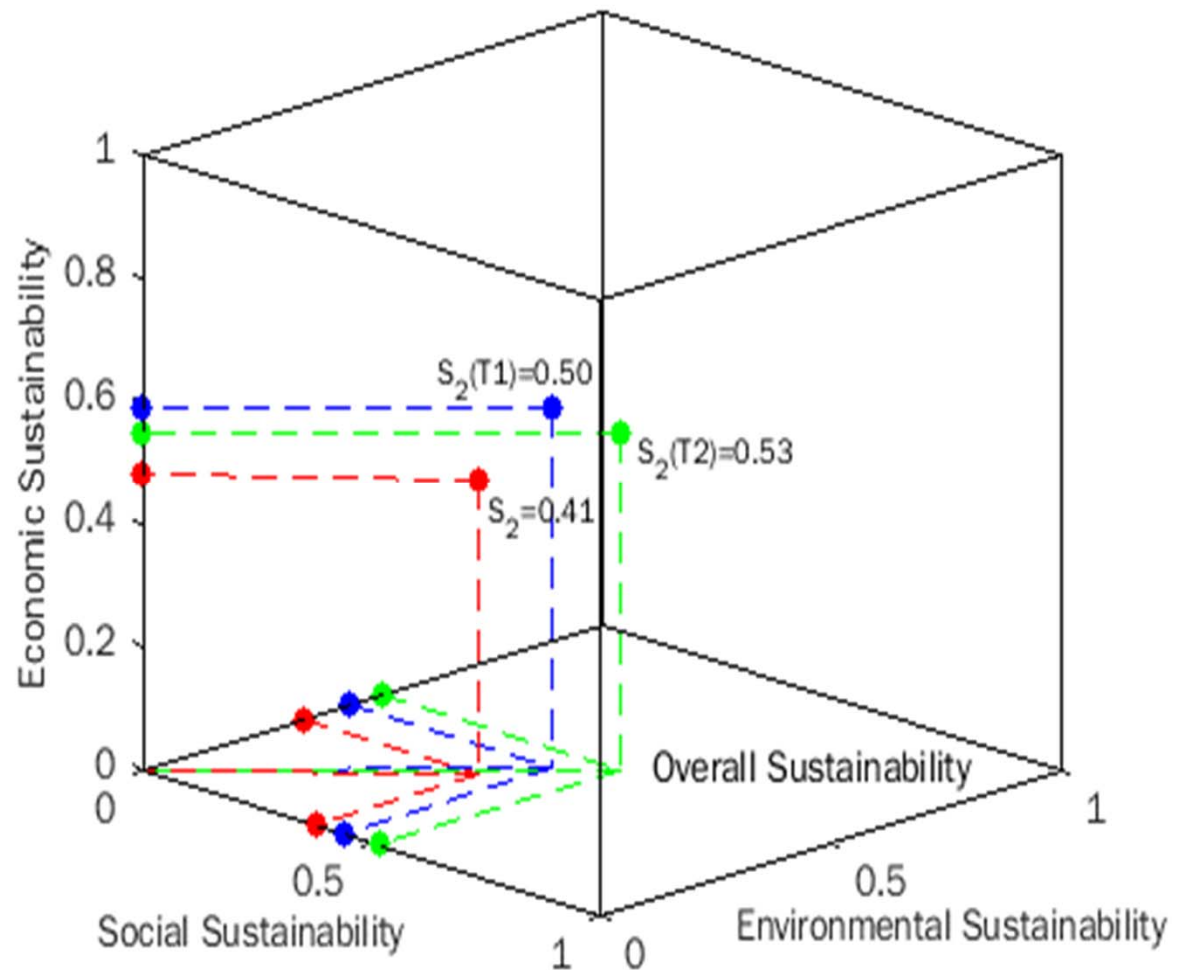


Case Study 2 – Results and Graphic Presentation

Comparison:

- **Overall Sustainability:**
0.41
- **Sustainability after implementing Tech 1:**
0.50
- **Sustainability after implementing Tech 2:**
0.53

Category	Original	Technology 1	Technology 2
Economic	0.48	0.59	0.55
Environmental	0.35	0.45	0.52
Social	0.38	0.44	0.52
Overall	0.41	0.50	0.53

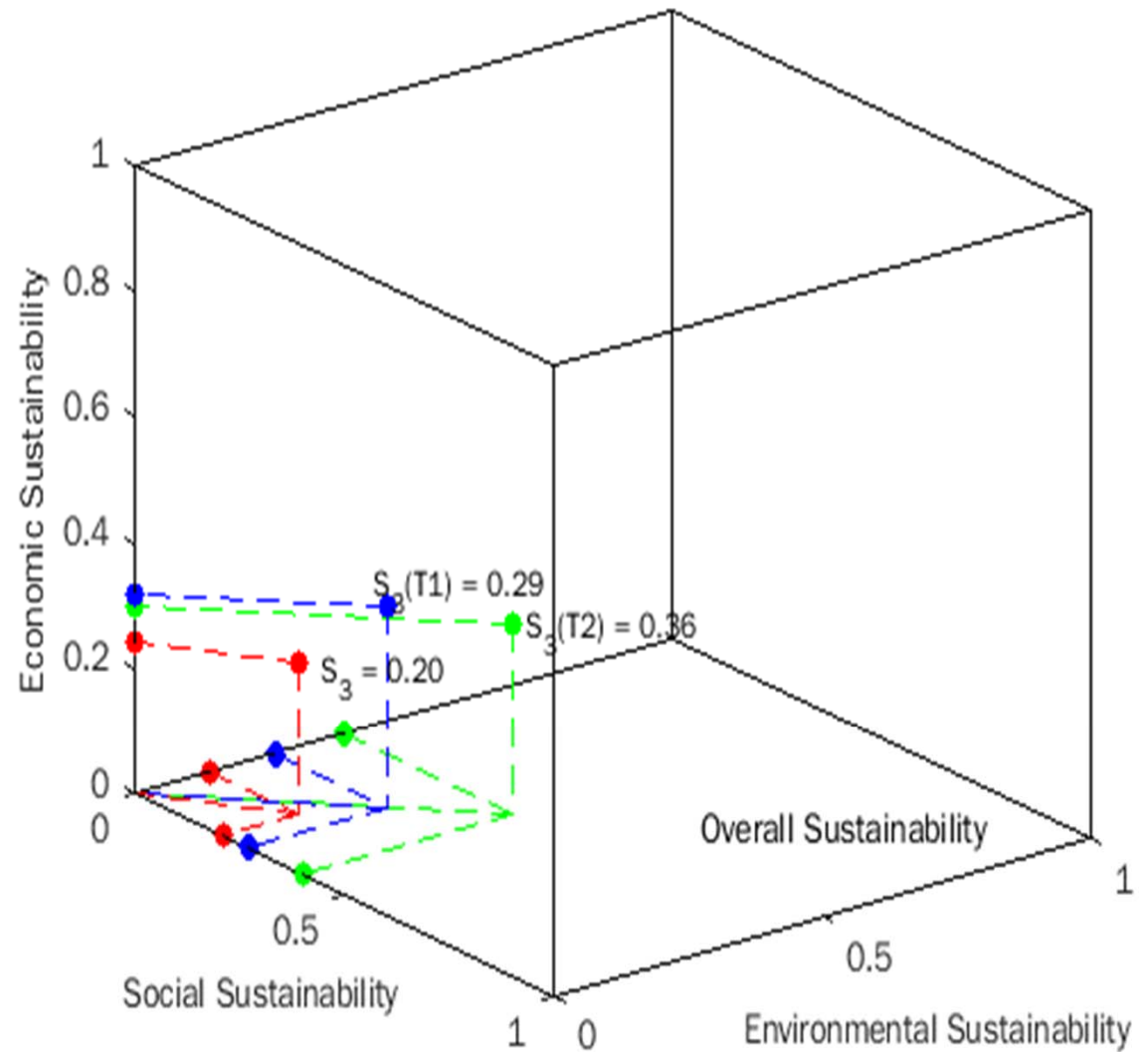


Case Study 3 – Results and Graphic Presentation

Comparison:

- **Overall Sustainability:**
0.20
- **Sustainability after implementing Tech 1:**
0.29
- **Sustainability after implementing Tech 2:**
0.36

Category	Original	Technology 1	Technology 2
Economic	0.24	0.32	0.30
Environmental	0.14	0.26	0.39
Social	0.21	0.27	0.40
Overall	0.20	0.29	0.36

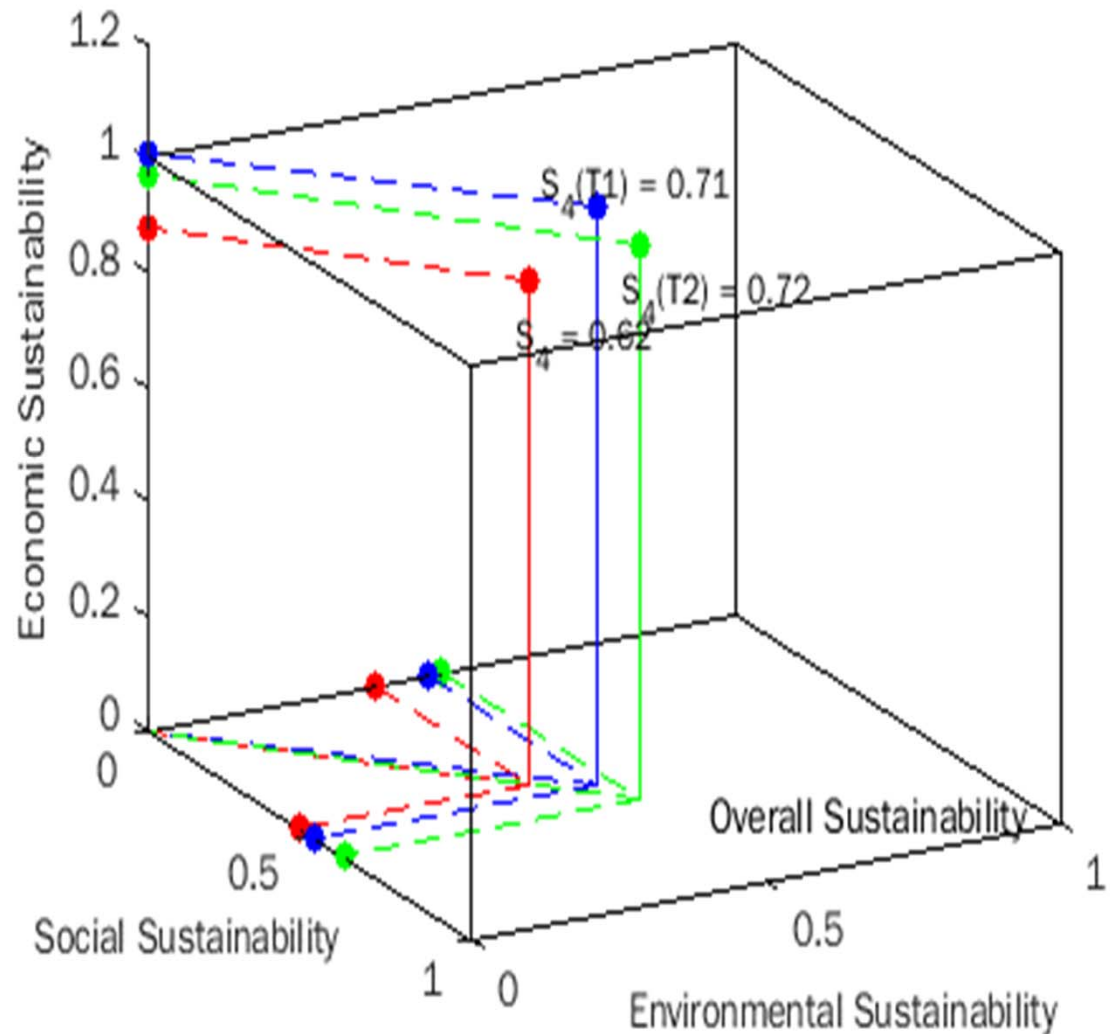


Case Study 4 – Results and Graphic Presentation

Comparison:

- **Overall Sustainability:**
0.62
- **Sustainability after implementing Tech 1:**
0.71
- **Sustainability after implementing Tech 2:**
0.72

Category	Original	Technology 1	Technology 2
Economic	0.88	1.01	0.97
Environmental	0.39	0.48	0.50
Social	0.47	0.52	0.61
Overall	0.62	0.71	0.72

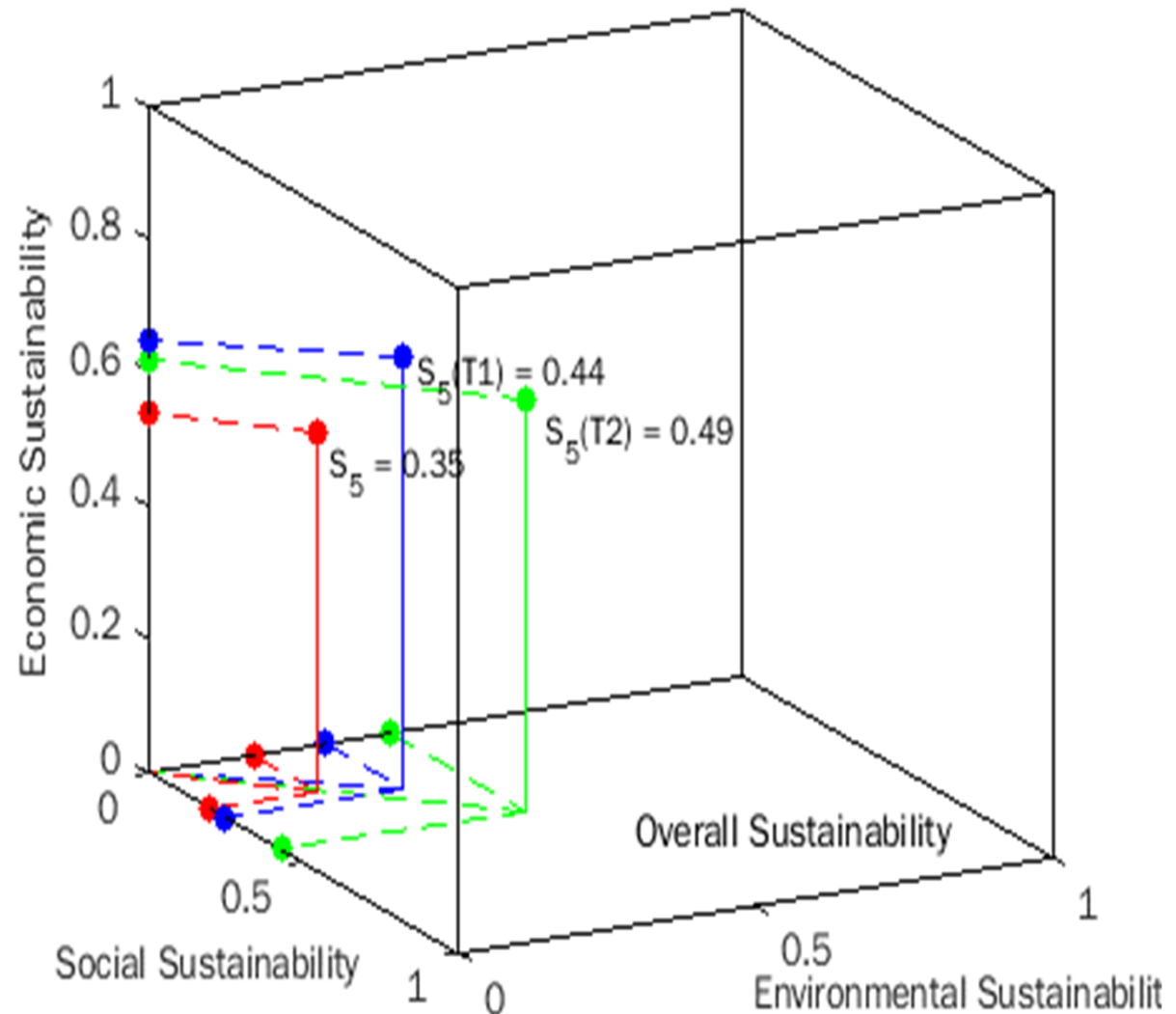


Case Study 5 – Results and Graphic Presentation

Comparison:

- **Overall Sustainability:**
0.35
- **Sustainability after implementing Tech 1:**
0.44
- **Sustainability after implementing Tech 2:**
0.49

Category	Original	Technology 1	Technology 2
Economic	0.54	0.65	0.62
Environmental	0.18	0.30	0.41
Social	0.20	0.25	0.43
Overall	0.35	0.44	0.49



Tool for Sustainability Assessment and Decision Making - ISAE

Industrial Sustainability Assessment and Enhancement (ISAE)

(v 1.1, Jan. 2022)

Laboratory for Multiscale Complex Systems Science and Engineering
Department of Chemical Engineering and Materials Science
Wayne State University, Detroit, Michigan, USA

Help

Assessment

Analysis

Decision Support

Exit

ISAE Tool – Indicator Selection Window

Please Select From the Following Sustainability Indicators

	Indicator Selection
Economic Indicators	
Profit, Value, and Tax	
Value Added (\$/y)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Value Added per Unit Value of sales (\$/y)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Value Added per Direct Employee (\$/y)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Gross Margin per Direct Employee (\$/y)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Return on Average Capital Employed (%/y)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Tax Paid as a Percentage of Net Income Before Tax (%)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Investments	
Percentage Increase (Decrease) in Capital Employed (%)	<input checked="" type="radio"/> Yes <input type="radio"/> No
R&D Expenditure as a Percentage of Sales (%)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Employees with Post-School Qualification (%)	<input checked="" type="radio"/> Yes <input type="radio"/> No
New Appointments per Number of Direct Employees (%)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Training Expense as a Percentage of Payroll Expense (%)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Investment in Education per Employee Training Expenses (\$/\$)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Charitable Gifts as a Percentage of Net Income Before Tax (%)	<input checked="" type="radio"/> Yes <input type="radio"/> No

	Indicator Selection
Environmental Indicators	
Resource Use	
Energy	
Total Net Primary Energy Usage (GJ/y)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Material (Excluding Fuel and Water)	
Total Raw Materials Used per Kg Product (Kg/Kg)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Total Raw Materials Used per Unit Value Added (Kg/\$)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Fraction of Raw Materials Recycled within Company (Kg/Kg)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Fraction of Raw Materials Recycled from Customers (Kg/Kg)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Hazardous Raw Material per Kg Product (Kg/Kg)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Water	
Net Water Consumed per Unit Mass of Product (Kg/Kg)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Net Water Consumed per Unit Value Added (Kg/\$)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Land	
Total Land Occupied and Effected per Unit Value Added (m ² /\$/y)	<input checked="" type="radio"/> Yes <input type="radio"/> No
Rate of Land Restoration (Restored per Year/Total) ((m ² /y)/m ²)	<input checked="" type="radio"/> Yes <input type="radio"/> No

Help

Continue Indicator Selection

Main Menu

ISAE Tool – Data Input Window

Please Input Values For The Following Economic Indicators

	Process-Product Design					Boundary Specification	
	A	B	C	D	E	Lower	Upper
Economic Indicators							
Profit, Value, and Tax							
Value Added (\$/y)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Value Added per Unit Value of sales (\$/y)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Value Added per Direct Employee (\$/y)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Gross Margin per Direct Employee (\$/y)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Return on Average Capital Employed (%/y)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Tax Paid as a Percentage of Net Income Before Tax (%)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Investments							
Percentage Increase (Decrease) in Capital Employed (%)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
R&D Expenditure as a Percentage of Sales (%)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Employees with Post-School Qualification (%)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
New Appointments per Number of Direct Employees (%)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Training Expense as a Percentage of Payroll Expense (%)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Investment in Education per Employee Training Expenses (\$/\$)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Charitable Gifts as a Percentage of Net Income Before Tax (%)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Help

Save and Next

Back

Main Menu

ISAE Tool – Assessment Summary

	E1	E2	E3	E4	E5	E6	E7
A	0.2222	0.3333	0.6667	0.2222	0.5556	0.5556	0.7778
B	0.5556	0.4444	0.7778	0.3333	0.4444	0.6667	0.6667

Economic Sustainability

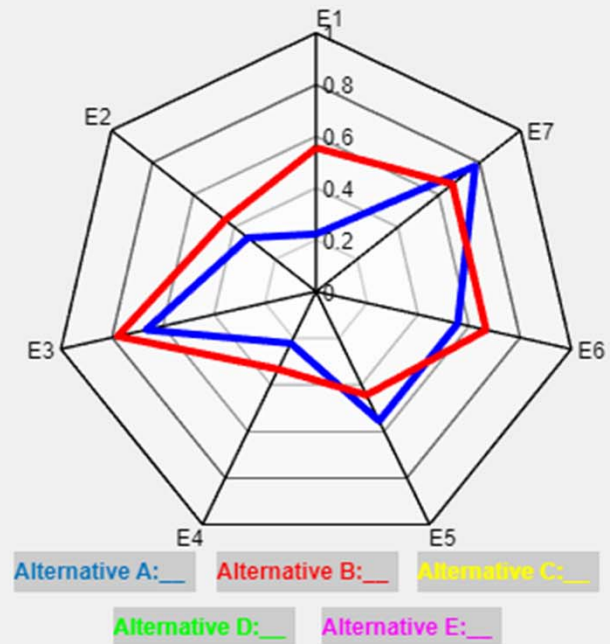
1. Value Added
2. Value Added per Unit Value of sales
3. Value Added per Direct Employee
4. Gross Margin per Direct Employee
5. Return on Average Capital Employed
6. Tax Paid as a Percentage of Net Income Before Tax
7. Percentage Increase (Decrease) in Capital Employed
8. R&D Expenditure as a Percentage of Sales
9. Employees with Post-School Qualification
10. New Appointments per Number of Direct Employees
11. Training Expense as a Percentage of Payroll Expense
12. Investment in Education per Employee Training Expenses
13. Charitable Gifts as a Percentage of Net Income Before Tax

Help

Save and Next

Back

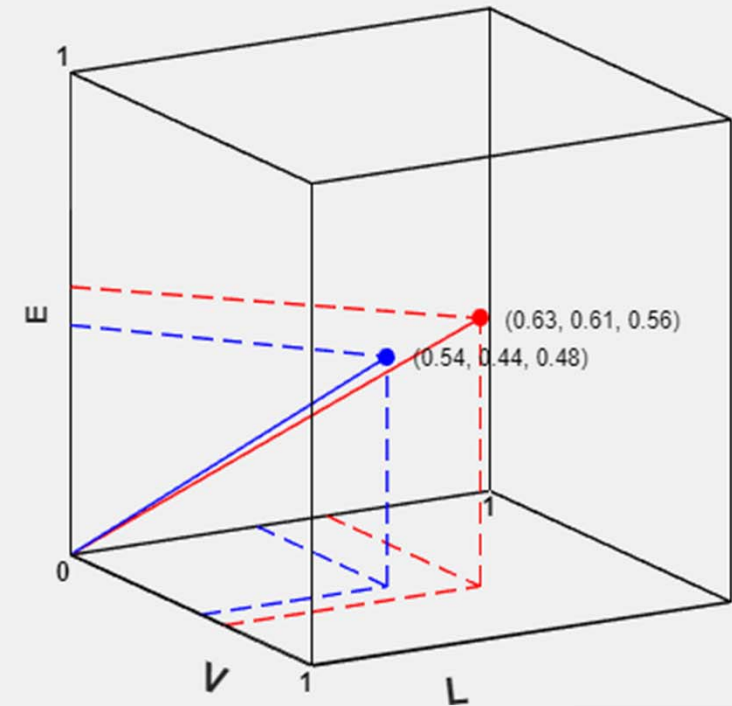
Main



ISAE Tool: Overall Sustainability Presentation

Assessment Results

	Process Product Designs				
	A	B	C	D	E
Econ [E]	0.47619	0.55556			
Environ [V]	0.53968	0.63492			
Social [L]	0.44444	0.61111			
Overall [S]	0.48838	0.60145			



Alternative A: __

Alternative B: __

Alternative C: __

Alternative D: __

Alternative E: __

Concluding Remarks

- **Technology assessment: essential for achieving sustainability goals**
- **Methodology: scientific, systematic, and general**
- **Case study**
 - **Tech 2 is better than Tech 1 for improving overall sustainability in each case, mainly due to the high improvements of environmental and social sustainability**
 - **Tech 1 is better than Tech 2 for improving economic sustainability and could be more favorable to stakeholders**
- **ISAE Tool (under development)**
 - **Currently supports sustainability assessment for up to 5 manufacturing facilities**

Sustainability Metrics System for Metal Finishing

For those who are interested in obtaining a copy of the sustainability metrics system and participating in evaluation of the metrics system, please contact:
Professor Yinlun Huang, Email: yhuang@wayne.edu

Evaluation of the Proposed Sustainability Metrics for Metal Finishing - AESF Research Project R-121

Project PI: Yinlun Huang, Professor, Department of Chemical Engineering and Materials Science, Wayne State University, Detroit, MI 48098
Email: yhuang@wayne.edu; Phone: 313-577-3771

Dear Colleagues: Funded by AESF Foundation, Wayne State University is developing a sustainability metrics system and a sustainable solution methodology for helping improve sustainability performance in metal finishing facilities. The purpose of this survey is to seek industry's help in evaluating a draft version of sustainability metrics system in terms of the appropriateness and importance of each indicator in different sustainability categories, and providing your comments and suggestions. Your feedback is highly valuable and we deeply appreciate your support. Yinlun Huang (Project PI), March 31, 2021

Date						
Organization (optional)			Address (optional)			
Contact Person (optional)			Email or Phone No. (Optional)			
Business Type	Electroplating ____	Other Type of Metal Finishing ____	Chemical Supply ____	OEM ____	Technology ____	Consulting ____
	Customer ____	Community or Other Stakeholder ____	Government ____	State/Local Agency ____	Professional Organization ____	Other ____
Job Responsibility/ Expertise (check all if appropriate)	Management _____		Health and Safety _____		Technology / Research _____	
	Process Engineering / Production _____		Supply / Sales _____		Education _____	
	Environmental _____		Customer Relation _____		Other _____	

Instruction:

1. In the "Rating of Importance" column, please enter a numerical number in each cell.
2. In the "Comments or Suggestions" column, you may provide your comments and/or suggestions on any listed indicators. You may also add new or modified indicators and share your thoughts about feasibility of data collection in your company.

Sustainability Metrics System for Metal Finishing

Economic sustainability Indicator (20 in 4 subcategories)

Environmental sustainability Indicators (19 in 4 subcategories)

Social sustainability Indicators (14 in 3 subcategories)

Subcategory	Indicator	Definition or Explanation	Rating of Importance (enter a number between 1 and 10, with 1 = least important and 10 = most important)
E-1: Profit, Value and Tax	E-1-1: Value Added (\$/yr)	Based on the difference between the product price to consumers and the manufacturing cost	
	E-1-2: Value Added per Direct Employee (\$/yr)	Average amount each employee adds in value to the company	
	E-1-3: Net Profit Margin (%/S)	Based on the difference between the income from produce sale after tax and the production cost	
	E-1-4: Net Profit per Direct Employee (\$/yr)	Average amount of profit each employee makes for the company	
	E-1-5: Tax Paid as a Percentage of NIBT (%)	Amount of tax paid as a percentage of Net Income Before Tax (NIBT)	
E-2: Investments	E-1-6: Return on Average Capital Employed (\$/yr)	Amount of money received back with respect to the average capital employed	
	E-2-1: Percentage Increase in Capital Employed (%/yr)	Increase of average capital employed from last year	
	E-2-2: Percentage of New Employees (%/yr)	Percentage of new employees hired in the company per year	
	E-2-3: Percentage of Training vs Payroll Expense (%)	Amount of money spent on training of employees as a percentage of payroll expense	
	E-2-4: Investment for Employee's Education/Training (\$)	Amount spent on employee education and training regarding important aspects of their jobs	
E-3: Technology Advancement	E-2-5: Investment on New Technology (%/yr)	Percent increase spent on new technology from last year	
	E-3-1: Production Increment Percentage per Dollar Investment on New Technology (%/\$-new tech)	Amount of production increase from last year vs the amount of money invested on new technologies since last year	
	E-3-2: Production Increment Percentage per Dollar Investment on Technology Improvement (%/\$-existing tech)	Amount of production increase from last year vs the amount of money invested on existing technology improvement since last year. Existing technology improvement does not include investment on new technologies	
	E-3-3: Production Quality Improvement Percentage per Dollar Investment on New Technology (%/\$-new tech)	Quality of production improvement from last year vs the amount of money invested on new technologies since last year	
	E-3-4: Production Quality Improvement Percentage per Dollar Investment on Technology Improvement (%/\$-existing tech)	Quality of production improvement from last year vs the amount of money invested on existing technology improvement since last year. Existing technology improvement does not include investment on new technologies	
	E-3-5: Waste Reduction Percentage per Dollar Investment on New Technology (%/\$-new tech)	Amount of waste reduced from last year vs the amount spent on new technologies since last year	
E-4: Production and Product Quality	E-3-6: Waste Reduction Percentage per Dollar Investment on Technology Improved (%/\$-existing tech)	Amount of waste reduced from last year vs the amount spent on existing technology improvement since last year. Existing technology improvement does not include investment on new technologies	
	E-4-1: Percentage of Product Delivered on Time (%)	Percent of product that was delivered on time based on total products delivered per year	
	E-4-2: Product Defect Rate During Production (%)	Amount of defected product vs the total amount of product made per year	
	E-4-3: Product Return Rate After Shipment (%)	Amount of product returned after shipment vs the amount of product shipped per year	

V-1: Materials (Excluding Fuel and Water)	V-1-1: Chemical Use in Production per Value Added (lb/\$)	Amount of chemical used in production per dollar of value added per year	
	V-1-2: Chemical Use in Production per Dollar of Product Sales (lb/\$)	Amount of chemical used in production per dollar of product sales per year	
	V-1-3: Chemical Use in Waste Treatment per Value Added (lb/\$)	Amount of chemical used in waste treatment per dollar of value added per year	
	V-1-4: Plating Solution Use per Value Added (lb/\$)	Amount of plating solution use per dollar of value added per year	
	V-1-5: Plating Solution Use per Dollar of Product Sales (lb/\$)	Amount of plating solution use per dollar of product sales per year	
	V-1-6: Other Material Use per Dollar of Product Sales (lb/\$)	Amount of other material use per dollar of product sales per year	
V-2: Water	V-2-1: Fresh Water Use in Production per Dollar of Product Sales (lb/\$)	Amount of fresh water use in production per dollar of product sales per year	
	V-2-2: Used Water Reused in Production before Treatment (%)	Percentage of used water reused in production per year before treatment of waste	
	V-2-3: Fraction of Water Recycled Within Plant (%)	Percentage of water recycled within the plant	
V-3: Energy	V-3-1: Electricity Use per Dollar of Sales (KW/\$)	Kilo Watts of electricity use per dollar of product sales per year	
	V-3-2: Natural Gas and Oil Use per Dollar of Sales (MMBtu/\$)	Million Btu of natural gas and oil use per dollar of product sales per year	
	V-3-3: Clean Energy Use Among All Energy (%)	Percentage of energy derived from "clean" sources vs all energy consumed	
V-4: Waste Generation and Effluents	V-3-4: Non-Production Energy Among All Energy Consumption (%)	Percentage of energy not used in production vs all energy consumed	
	V-4-1: Spent Solutions per Value Added (lb/\$)	Amount of spent solution per dollar value added per year	
	V-4-2: Wastewater Generated in Production per Value Added (lb/\$)	Amount of wastewater generated in production per dollar of value added per year	
	V-4-3: Wastewater Treatment Sludge per Value Added (lb/\$)	Amount of wastewater treatment sludge used per dollar of value added per year	
	V-4-4: Hazardous Waste Generated per Value Added (lb/\$)	Amount of hazardous waste generated per dollar of value added per year	
	V-4-5: Non-Hazardous Waste Generated per Value Added (lb/\$)	Amount of non-hazardous waste generated per dollar of value added per year	

L-1: Workplace	L-1-1: Benefits as Percentage of Payroll Expense (%)	Benefits to employees as a percentage of total payroll expenses per year	
	L-1-2: Work Related Re-Education and/or Training (%)	Amount of money spent on work related reeducation and training vs total payroll expenses per year	
	L-1-3: Employee Turnover (%)	Resigned and redundant employees vs total employed per year	
	L-1-4: Promotion Rate (%)	Number of Promotions vs total employed per year	
L-2: Safety and Health	L-1-5: Working Hours Lost as Percentage of Total Hours Worked (%)	Working hours lost vs total hours worked per year	
	L-2-1: Number of Process Safety Reviews (/yr)	Number of process safety reviews per year	
	L-2-2: Number of Accidents in Workplace (/yr)	Number of accidents in the workplace per year	
	L-2-3: Chemical Leakage in Plant (/yr)	Amount of chemical leakage in plant per year	
L-3: Society	L-2-4: Human Health Burden (Carcinogenic) per Value Added (/S)	Number of people in the workforce and local community with carcinogenic health conditions as a result of the plant per dollar of value added per year	
	L-3-1: Number of Stakeholder Meetings (/yr)	Number of stakeholder meetings per year	
	L-3-2: Indirect Community Benefit (\$/yr)	Amount of money spent with indirect community benefit per year	
	L-3-3: Number of Complaints from Local Community (/yr)	Number of complaints from the local community per year	
	L-3-4: Number of Complaints from Customers (/yr)	Number of complaints from customers per year	
	L-3-5: Number of Legal Actions per Value Added (/yr)	Number of legal actions per dollar of value added per year	

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