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New Tools For Sustainability Analysis: Capturing Life Cycle Costs and Impacts in Defense Acquisition

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Noblis

Short Course 3C

SERDP • ESTCP
25 YEARS OF ESTCP
SYMPOSIUM
2019 | Enhancing DoD's Mission Effectiveness

New Tools For Sustainability Analysis:

Capturing Life Cycle Costs and Impacts in Defense Acquisition

- **Course overview:**
  - Demonstrating that a chemical, process, or product is more sustainable or greener than the original requires data, tools, and interpretation. DoD's Sustainability Analysis method provides researchers and program officers with a way to collect and produce the evidence needed to support decisions that promote sound environmental stewardship.
- **This short course will:**
  - Describe Life Cycle Thinking / Sustainability Analysis at DoD
  - Briefly show how results of Sustainability Analysis were useful to analysts/program managers/etc.
  - Identify data, software, and other resources for Sustainability Analysis
  - Provide hands-on exercises with Excel and a web tool, SparkLC, so that attendees can conduct a basic Sustainability Analysis

Agenda

- **How this can help you**
  - Examples of Sustainability Analysis , i.e., systems thinking, in SONs (how this can help you)
- **Quick review**
  - Systems thinking
  - Case study
- **How you can do an analysis**
  - Tools available
  - Manual calculation
  - Using SparkLC (https://sparklc.noblis.org/)

Life Cycle Thinking in SERDP Statements of Need

Example: Development of Advanced Coating System (WPSON-20-C1)

- **Objective: New, innovative advanced protective coatings and systems**
  - Improved protective properties
  - Require few resources
  - Easier to use
  - Environmentally sustainability
- **The "new" system must be able to meet performance requirements …**
  - Operational protective properties
  - Less complex application techniques
  - Ability to selectively strip or apply coatings
- **… and, it must be more sustainable …**
  - Reduced life cycle costs and impacts associated with human health and the environment
  - Energy efficient
  - Improved chemistry
- **… when compared with current and legacy systems.**

Life Cycle Thinking in SERDP SEED Proof of Concept

Example: Reduction of Hazardous Waste Streams from Composite Manufacturing and Repair (WPSEED-20-S1)

- **Objective: Enable reuse or recycle of composite material**
  - Reduce waste
  - Reduce environmental and worker exposures to chemicals and particulates
  - Reduce impact of composite material waste (millions of pounds of hazardous waste)
- **The "new" system must perform …**
  - Manage shelf-life and expiring materials
  - Identify scrap uses
  - Change the way composite materials are produced
- **… and, it must be more sustainable …**
  - Reduced life cycle costs and impacts associated with human health and the environment
- **… when compared with current and legacy systems.**

The DoD Portfolio for Sustainability Analysis…

- Builds awareness with policy makers and practitioners
- Provides guidance and support to enable success
- Delivers tools and resources that make it “easier” to do

…readies you to respond to SONs and BAAs which ask you to…

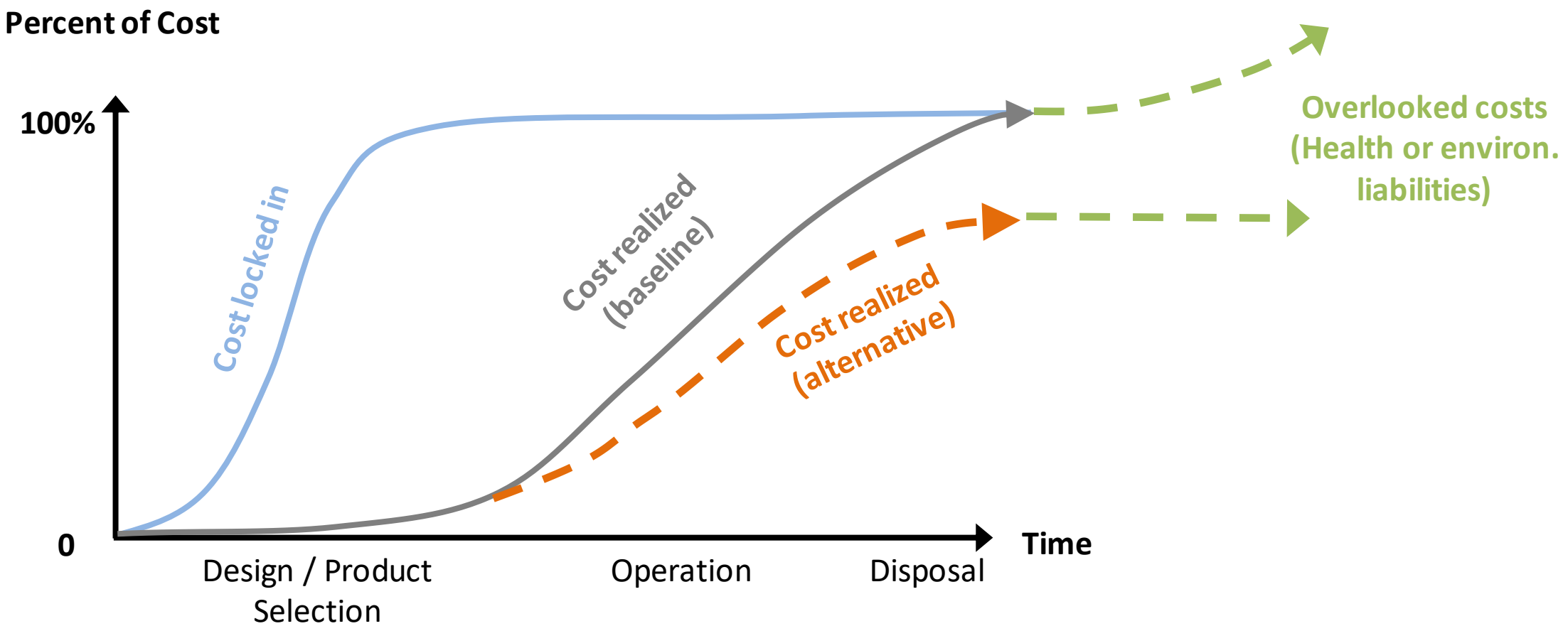
- Develop a baseline life cycle framework
- Identify elements of a life cycle inventory
- Conduct a preliminary LCA to assess cost, health, and environmental impacts of proposed approach
- Perform an initial assessment of human health and environmental impacts of proposed ingredients, formulations, byproducts

National Defense Strategy (NDS) 2018

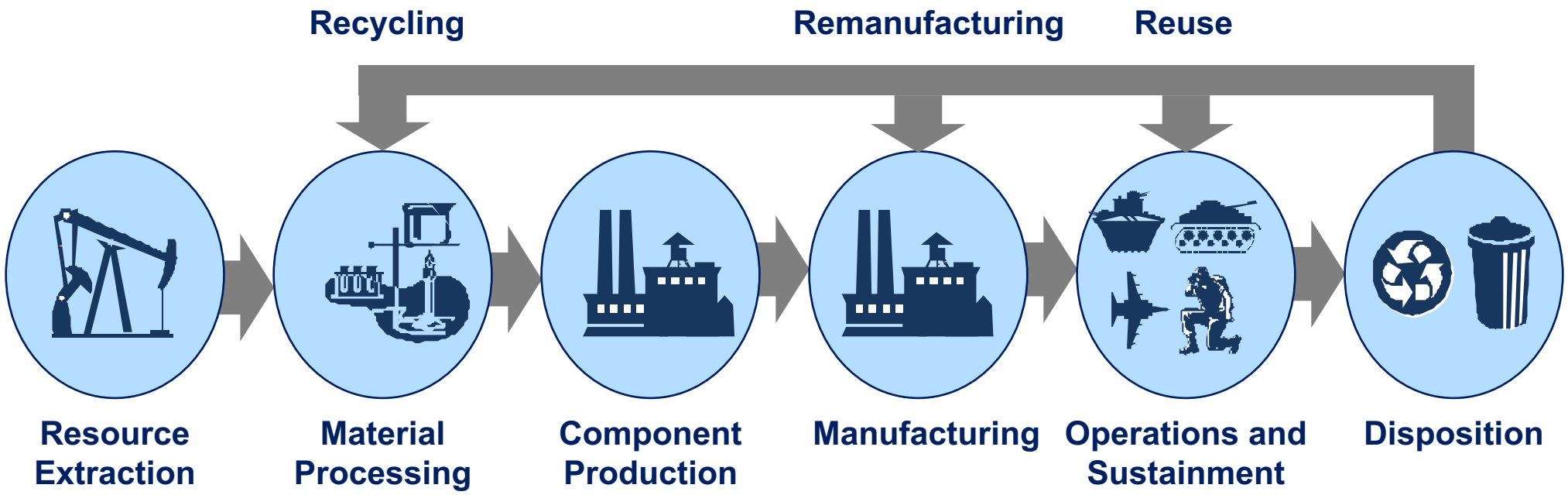
Includes Costing

- **NDS goals**
  - Increase lethality
  - Strengthen and build alliances
  - Improve performance and affordability
- **Already plenty of guidance to address affordability**
  - DoD 5000.04-M, Product Support Business Case Analysis Guidebook
- **But…**

We Need to Anticipate Holistically to Compare Alternatives Comprehensively



What is Life Cycle Thinking?

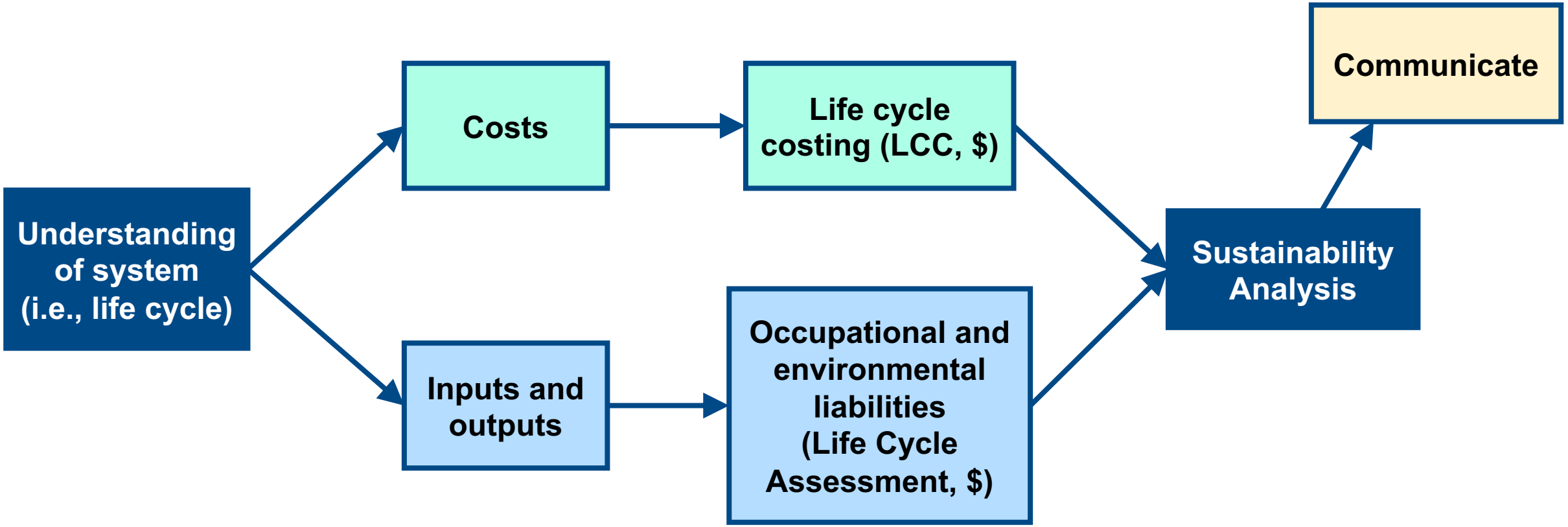


Types of Questions for Life Cycle Thinking

- Would on-site water treatment require more energy than available supply?
- How much would a new explosives production line save in terms of long-term medical costs for workers?
- How much would a cadmium-free plating line save in haz waste costs?

- **i.e., “Is the cost / health / environment tradeoff acceptable?”**

What is the DoD Sustainability Analysis framework?



Types of Costs Considered

Direct Internal Cost	Indirect Internal Cost	Contingent Internal Cost	External Cost (social cost)
• Procurement cost of material • System manufacturing	• Procurement cost of PPE • Hazardous waste management	• Clean up of pollution • Medical cost for DoD personnel • Substitute development and testing	• Damage to human health • Damage to ecosystem quality Not to be summed with others

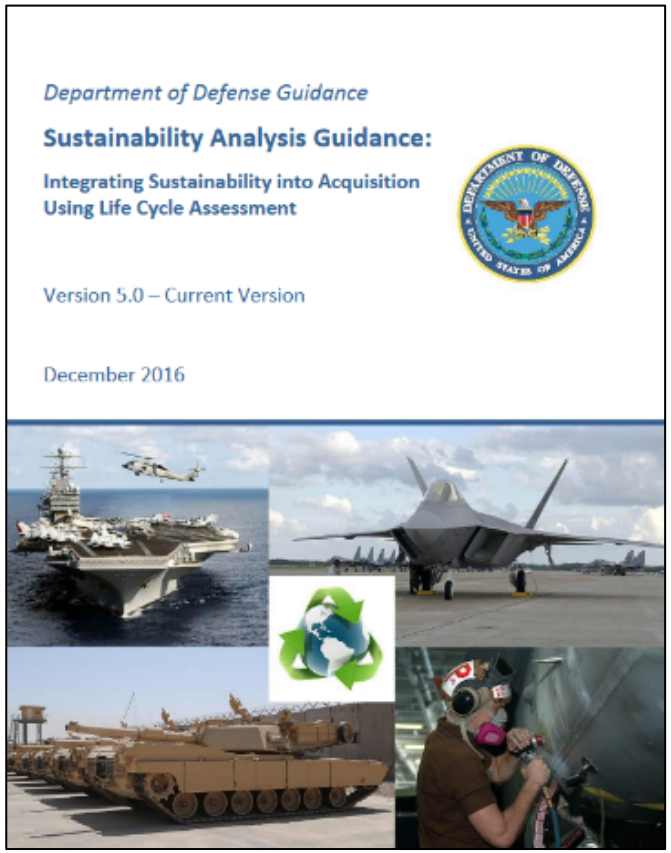
Revealed and quantified using LCC estimating.

Systems thinking may help to identify other costs.

Revealed and quantified through LCA.

Sustainability Analysis Guidance Document

- The Defense Acquisition Guidebook requires performance of a Sustainability Analysis for all systems. The document:
  - Offers a consistent, practical, flexible methodology
  - Can be used to develop the scope, inventory, impact assessment, cost assessment
  - Uncovers previously hidden human health and environmental impacts and their associated life cycle costs
  - Can be used to identify the most sustainable alternative among those that meet performance requirements
  - Is available at http://www.denix.osd.mil/esohacq/home/


Department of Defense Guidance

Sustainability Analysis Guidance:

Integrating Sustainability into Acquisition Using Life Cycle Assessment

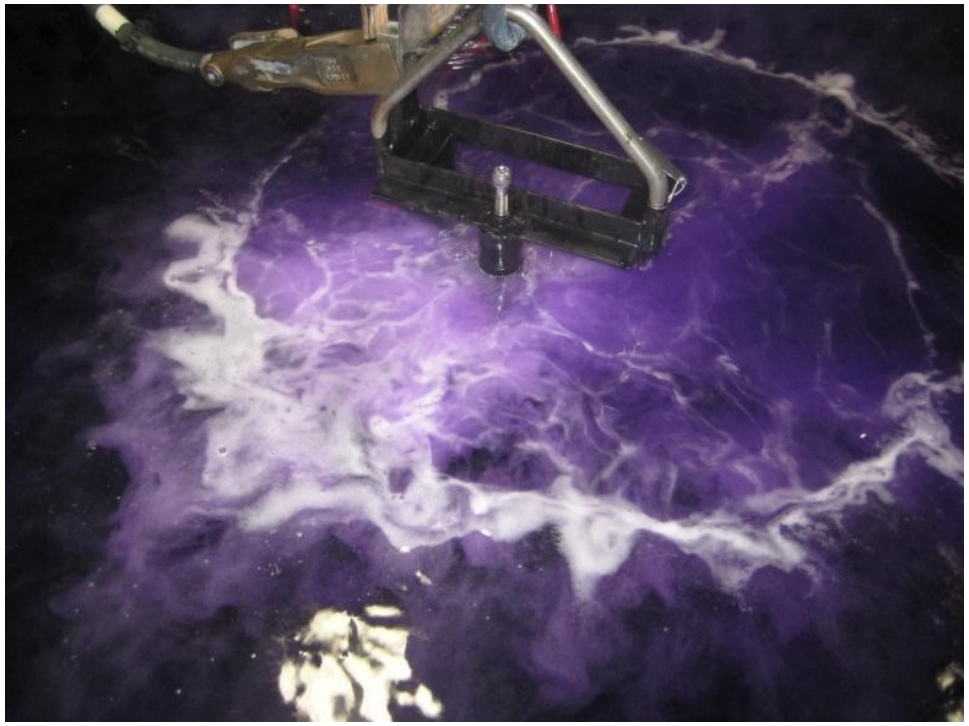
Version 5.0 – Current Version

December 2016

Case Study

Switch to zinc-nickel (Zn-Ni) from cadmium (Cd) electroplating

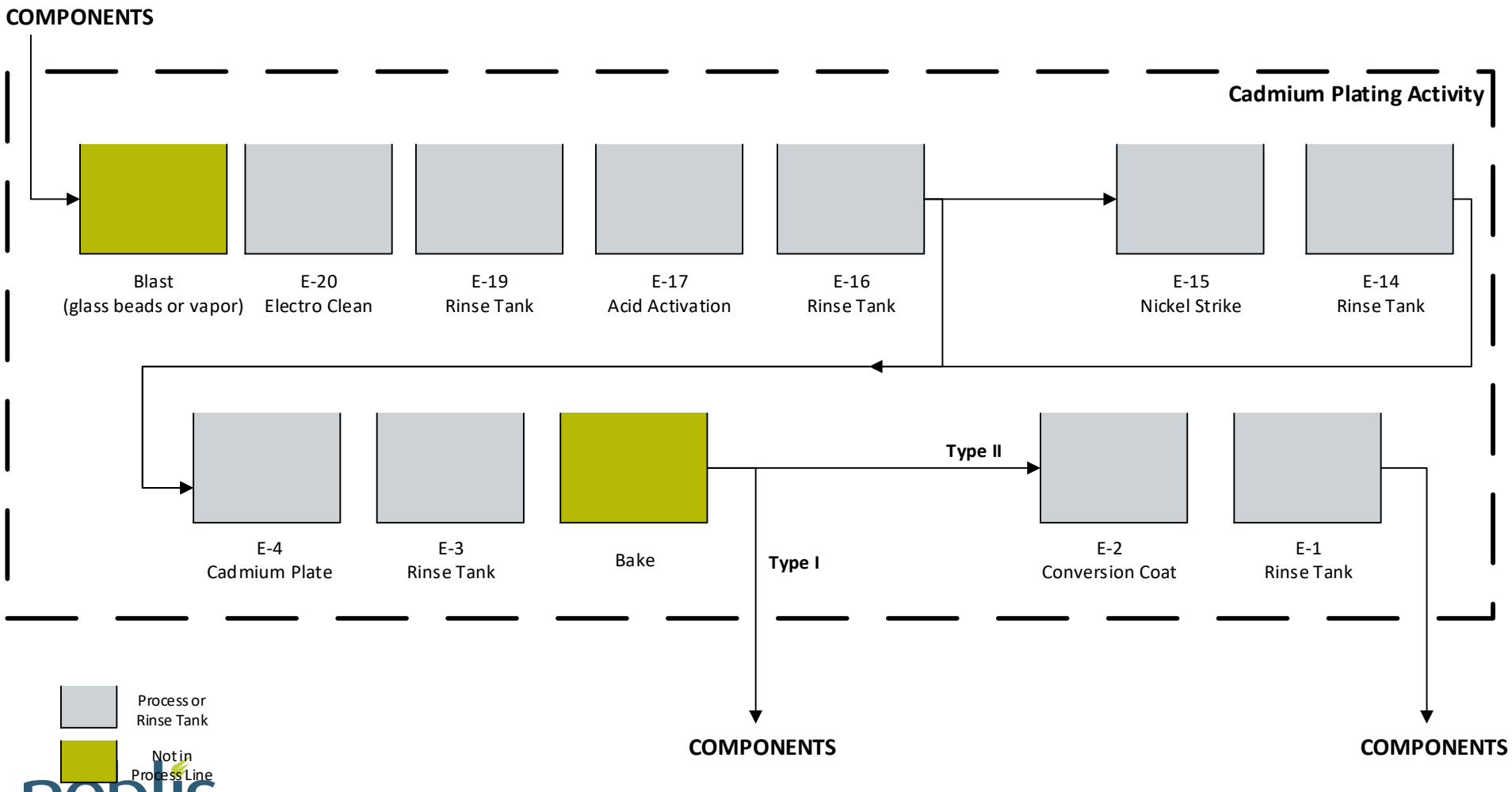
- **Objectives:**
  - Understand cost over life cycle
  - Understand environment, occupational health impacts
  - Office Assistant Secretary of Defense (OASD): Avoid burden-shifting throughout portfolio
  - Fleet Readiness Center Southeast (FRCSE): Communicate results up the command chain (e.g., build business case)



Low Hydrogen Embrittlement Zn-Ni Plating at Hill AFB

(ESTCP Project WP-201107)

Plating Line: Cd Baseline



- 15-year lifespan
- Capital costs associated with line installation are sunk
- Inputs and outputs for components with and without post-treatment are included

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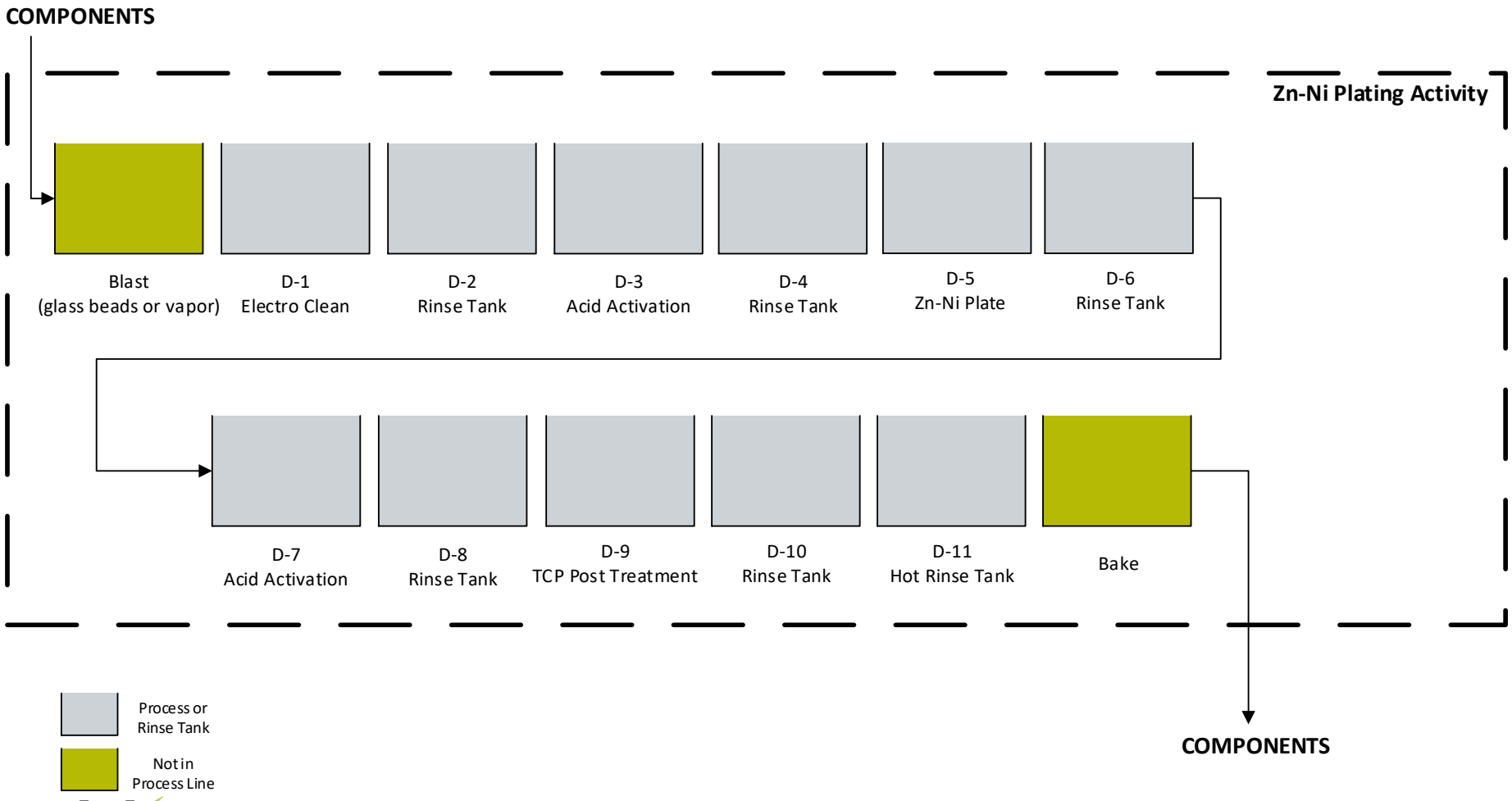
Plating Line: Zn-Ni Alternative



- 15-year lifespan
- Capital costs associated with line installation included
- High and low labor estimate scenarios

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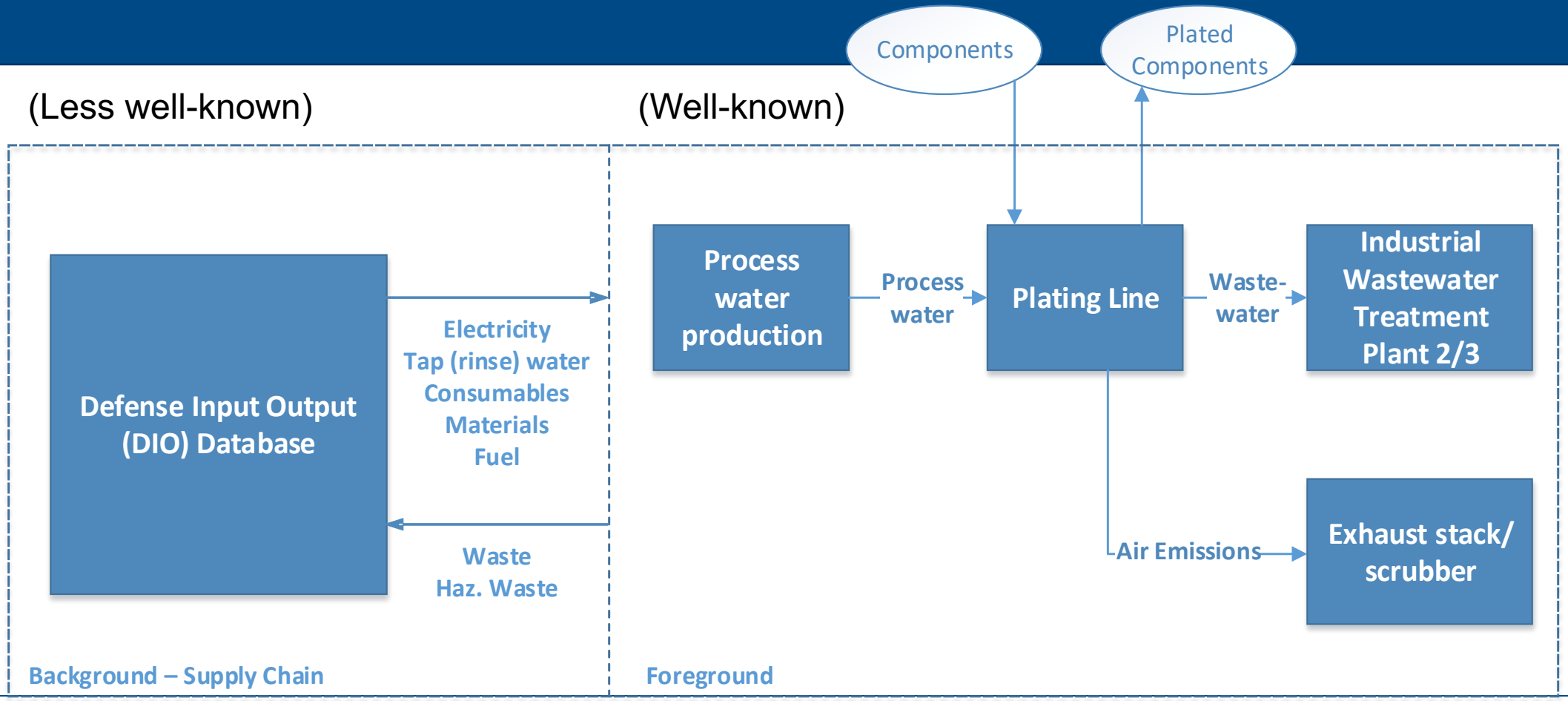
Scope of Comparison: Tiered Approach



- Costs and environmental impacts are compared per ft^2 of plating over a 15-year life span
- The system boundary includes the plating line, support infrastructure, and the supply chain

Case Study Conclusions

- **Opportunities for improvement**
  - Corrosion testing may indicate longer life of components or less frequent repair plating
  - Parameters of higher importance could be explored further (e.g., labor, investment costs)
- **How can results be used?**
  - Communicate results up the command chain (e.g., build business case)
  - High level picture of benefits and drawbacks (cost, quantitative, and qualitative) for alternative

Tools and Resources for Sustainability Analyses

- **There are databases, models, and software tools available to help you to do a life cycle-based assessment or a Sustainability Analysis.**
  - Defense-based environmentally extended input output model (DIO)
  - Characterization factors, including DoD Scoring Factors
  - Spreadsheets or open-source software (learning curve)
  - SparkLC web tool available to SERDP-ESTCP PIs (easier to get started quickly; based on DoD requirements)

Examples of Publicly Available Data

- Scoring Factors – DoD
- U.S. Environmental Protection Agency, U.S. Environmentally Extended Input-Output (USEEIO) Model
- USDA LCA Commons, Life Cycle Inventory database with agriculture focus
- U.S. Life Cycle Inventory database, providing U.S. based LCI data, polymers and more! available at https://uslci.lcacommons.gov/uslci/search
- NETL, Unit Process Library at www.netl.doe.gov/LCA
- NREL, Feedstock Production Emissions to Air Model (FPEAM) quantifying air emissions inventory for biofuels production system
- ANL, GREET LCA model (with GREET1—fuel cycle model; GREET2—vehicle cycle model; CCLUB—land use change model for biofuels)
- Berkeley Lab, Lifecycle Industry GHgas Technology Energy through the Use Phase (LIGHTnUP) analysis tool available at https://eaei.lbl.gov/tool/LIGHTEnUP
- NIST, BIRDS and BEES for building sustainability associated with energy, environment, and costs

Scoring Factors

- **384k entries:**
  - Lots of data, but takes some sorting or multi-criteria matching
- **Identifying info**
  - Factor Classification
  - Factor Type
  - Inventory Element
  - Inventory Item
  - Item Code (CAS #, NAICS, Occupation Code)
  - Location
  - Compartment
  - Compartment Description
  - Inventory Item Unit
- **"Midpoint" values**
  - Climate change
  - Respiratory inorganics
  - Respiratory organics
  - Carcinogens, unspecified
  - Carcinogens, indoor
  - Carcinogens, pesticide
  - Non-carcinogens, unspecified
  - Non-carcinogens, indoor
  - Non-carcinogens, pesticide
  - Water deprivation
  - Fossil energy use
  - Land use
  - Mineral use
  - Aquatic ecotoxicity
  - Noise, human exposure, outdoor
  - Noise, human exposure, indoor
- **"Endpoint" values**
  - Resource Availability
  - Climate Change
  - Human Health
  - Environmental Quality
- **Summary values**
  - External Cost

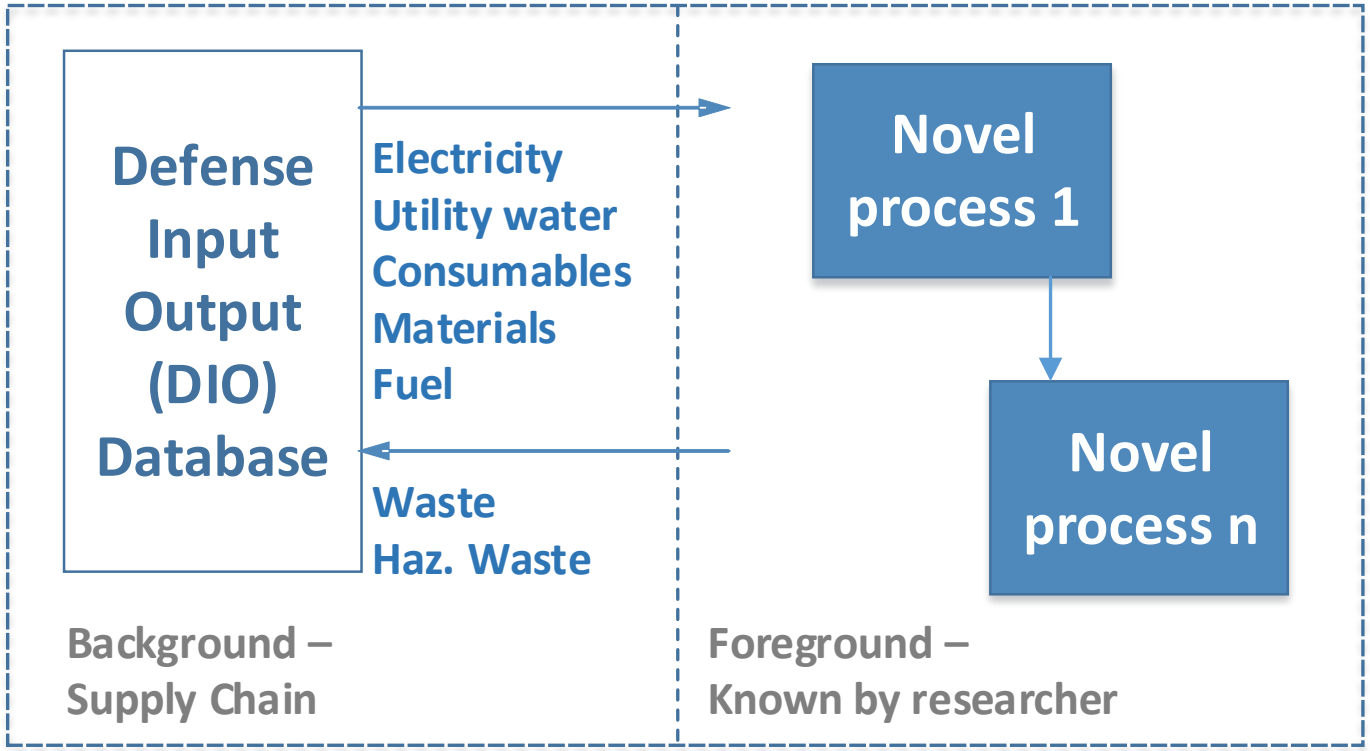
https://www.denix.osd.mil/esohacq/home/

Scoring Factors

Factor Class.	Factor Type	Inventory Element	Inventory Item	Inventory Item Unit	Resource Avail.	Climate Change	Human Health	Environ. Quality	External Cost
					MJ extra	*kg CO2-eq*	*DALY*	*PDF*m2*y*	USD2014
Input	Supply Chain	Chemicals & Materials	Oilseed farming (1111A0)	USD2014	2.0E+00	7.1E-01	3.2E-07	2.1E+00	1.9E-01
Input	Supply Chain	Chemicals & Materials	Synthetic dye and pigment manufacturing (325130)	USD2014	7.2E+00	9.5E-01	6.1E-07	5.8E-02	2.4E-01
Input	Supply Chain	Chemicals & Materials	Other basic inorganic chemical manufacturing (325180)	USD2014	4.7E+00	1.0E+00	9.6E-07	2.8E-02	2.5E-01
Input	Supply Chain	Chemicals & Materials	Other basic organic chemical manufacturing (325190)	USD2014	9.1E+00	1.2E+00	3.2E-07	4.8E-01	1.8E-01
Input	Supply Chain	Chemicals & Materials	Plastics material and resin manufacturing (325211)	USD2014	8.0E+00	9.3E-01	2.6E-07	1.7E-01	1.4E-01
Input	Activity (energy use)	Energy	No. 5 fuel oil combustion in ship	L	1.6E+01	3.6E+00	2.3E-06	7.1E-03	6.2E-01
Input	Activity (energy use)	Energy	Jet kerosene combustion in twin engine light bomber (ex. A-10A)	flight-h	2.1E+01	6.0E+03	4.9E-04	9.2E-03	3.2E+02
Input	Activity (transportation)	Other Costs	Truck transport, class 8, heavy heavy-duty (HHD), diesel, long-haul, load factor 0.75	t-km	7.8E-01	1.2E-01	2.1E-08	3.5E-04	1.3E-02

DIO Database (from which Scoring Factors are derived)

- Database, rather than flat
- Easier to use (via tool) but slightly more difficult to inspect (multiple matrices)
- DIO (and Scoring Factors) are coarse: no distinction between TCE and PFAS unless you model the difference
  - E.g., you model emissions of specific substance, or assign different contingent costs



Example System

DIO Database
Water, chemicals, electricity, etc.

Based on NAICS codes

Product

--Inputs--

Lime	5 kg	5 USD (direct)
Electricity	40 kWhr	40 kWhr (indirect)
Labor	0.25 hr	25 USD (direct)
		0.25 USD (contingent)

--Outputs--

Product_1	1 item

Inputs	Units	Direct	Indirect	Contingent
Labor	hr	$ 100	$ -	$ 1
Electricity	kWhr	$ -	$ 0.1	$ -
Lime	Kg	$ 1	$ -	$ -

Manual Calculation vs. LCA Tool, SparkLC

Manual

- Calculate/estimate inputs required
  - Check units, convert units
- Calculate/estimate costs
- Sum across system, tracking cost types
- Connect to Scoring Factors

Tool

- Calculate/estimate inputs required
  - Check units
- Calculate/estimate costs
- Add system to SparkLC

Inventory for Example – Convert and Scale

Inputs	Amount	Units	Direct	Indirect	Contingent
Labor	1	hr	$ 100.00	$ -	$ 1
Electricity	1	kWhr	$ -	$ 0.1	$ -
Lime	1	Kg	$ 1.00	$ -	$ -

Inputs	Amount	Units	Direct	Indirect	Contingent
Labor	0.25	hr	$ 25.00	$ -	$ 0.25
Electricity	40	kWhr	$ -	$ 4.00	$ -
Lime	5	kg	$ 5.00	$ -	$ -
Total Cost			**$ 30.00**	**$ 4.00**	**$ 0.25**

Connect to Scoring Factors

	A	B	C	D	E	F	AD	AE
1	NOTE: Factors designated as "Activity" include all per-unit inputs and outputs associated with the specified activity. No additional modeling is require						Valuation	
2	Factor Classification	Factor Type	Inventory Element	Inventory Item	Item Code (CAS #, NAICS, Occupation Code	Location	External Cost	
252	Input	Supply Chain	Chemicals & Materials	Other basic inorganic chemical manufacturing	32518	United States	2.4685E-01	
521	Input	Activity (energy use)	Energy	Electricity use, average generation mix	<n.a.>	District of Columbia,	3.6670E-02	
565	Input	Activity (energy use)	Energy	Electricity use, average generation mix	<n.a.>	United States	2.6029E-02	
384269								

Manual Calculation vs. LCA Tool, SparkLC

Manual

- Calculate/estimate inputs required
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Tool

- Calculate/estimate inputs required
  - Check units
- Calculate/estimate costs
- Add system to SparkLC

Web Tool Demo, https://sparklc.noblis.org/

Plate 1

Inputs

Name
Coating, engraving, heat treating and allied activities (332800) - US
Electricity use, average generation mix, Florida - US
Other basic inorganic chemical manufacturing (325180) - US
DI Water
Water, sewage and other s

Outputs

Name
Plate 1

Plate 2a

Inputs

Name
Electricity use, average generation mix, Florida - US
Other basic inorganic chemical manufacturing (325180) - US

Name
Plate 2a

Plate 2b

Inputs

Name	Amount	Units
Electricity use, average generation mix, Florida - US	1200.00000	kWh
Water, sewage and other systems (221300) - US	6000.00000	USD 2007
DI Water	1600.00000	gal (US liq)
Truck transportation (484000) - US	1000.00000	USD 2007
Natural gas combustion, small conventional low NOx burner (<100	8000.00000	m3
	0.00000	USD 2007
	0.00000	USD 2007

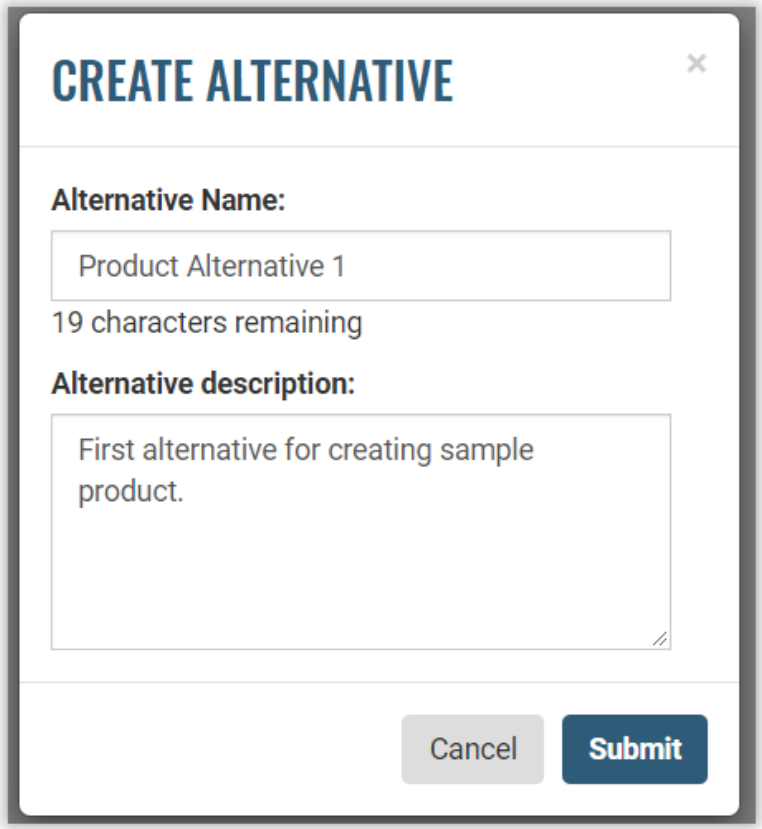
Outputs

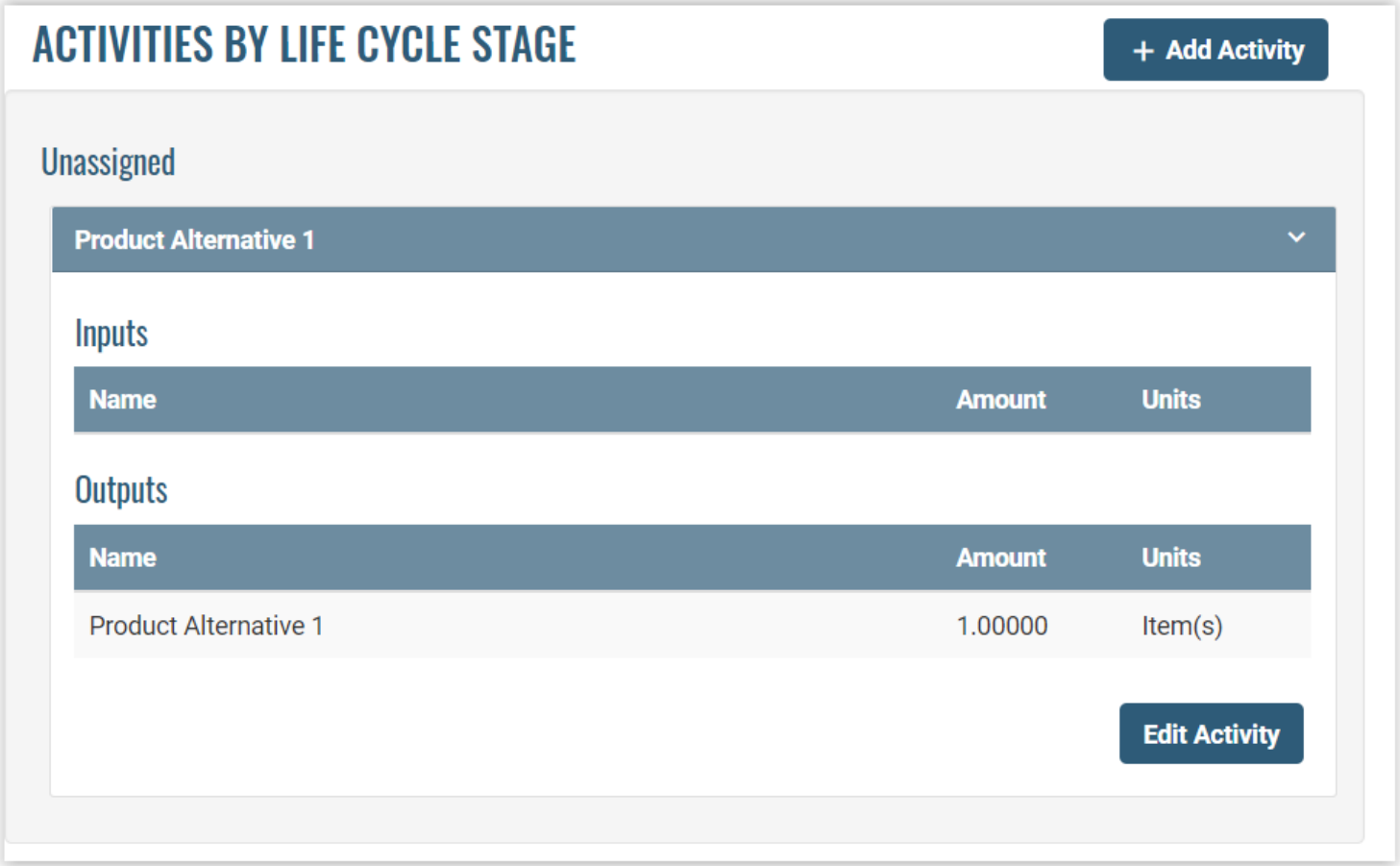
Name	Amount	Units
Plate 2b	1737.00000	ft2

Edit Activity

The tool is meant to be flexible, so there are choices to be made.
We'll start simply today.

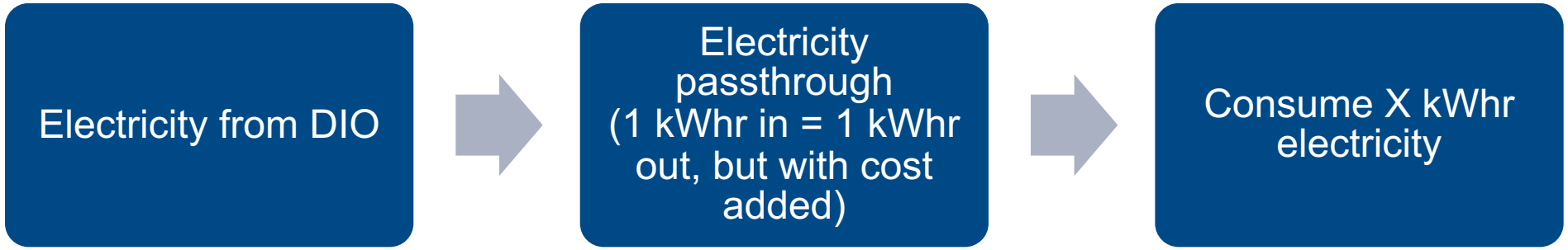
Create the ‘Reference’ Activity Based on Name





Considerations for SparkLC

- Create supporting activities before adding them to the reference (main) activity. (The main activity is created when the alternative is created.)
- Passthrough processes
  - May seem counterintuitive to set up, but passthroughs add tremendous flexibility.
  - Note that $ in DIO are not necessarily $ in your projects.



PT_Electricity

Inputs

Name	Amount	Units
Electricity use, average generation mix, District of Columbia - US	1.00000	kWh

Outputs

Name	Amount	Units
PT_Electricity	1.00000	kWh

Edit Activity

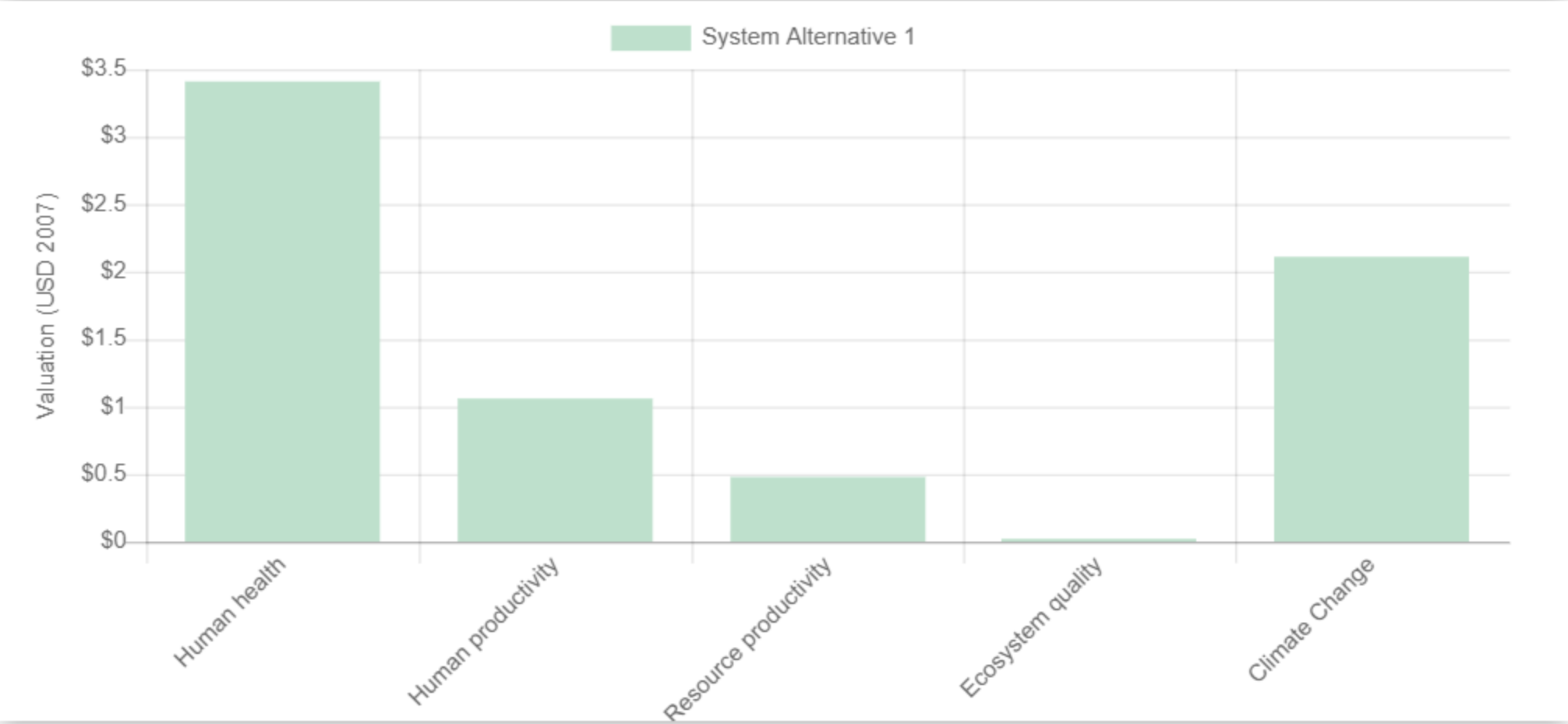
Example system: creating activities

- PT_Electricity
  - In: 1 kWhr from DIO
  - Out: 1 kWhr
  - Cost: $0.01 indirect
- PT_Labor
  - In: 1 hr (custom flow)
  - Out: 1 hr of “PT_Labor”
  - Cost: $100 direct, $1 contingent
- PT_Lime
  - In: $1 DIO of NAICS 325180, inorganic chem manufacturing
  - Out: 1 kg of PT_Lime
  - Cost: $1 direct

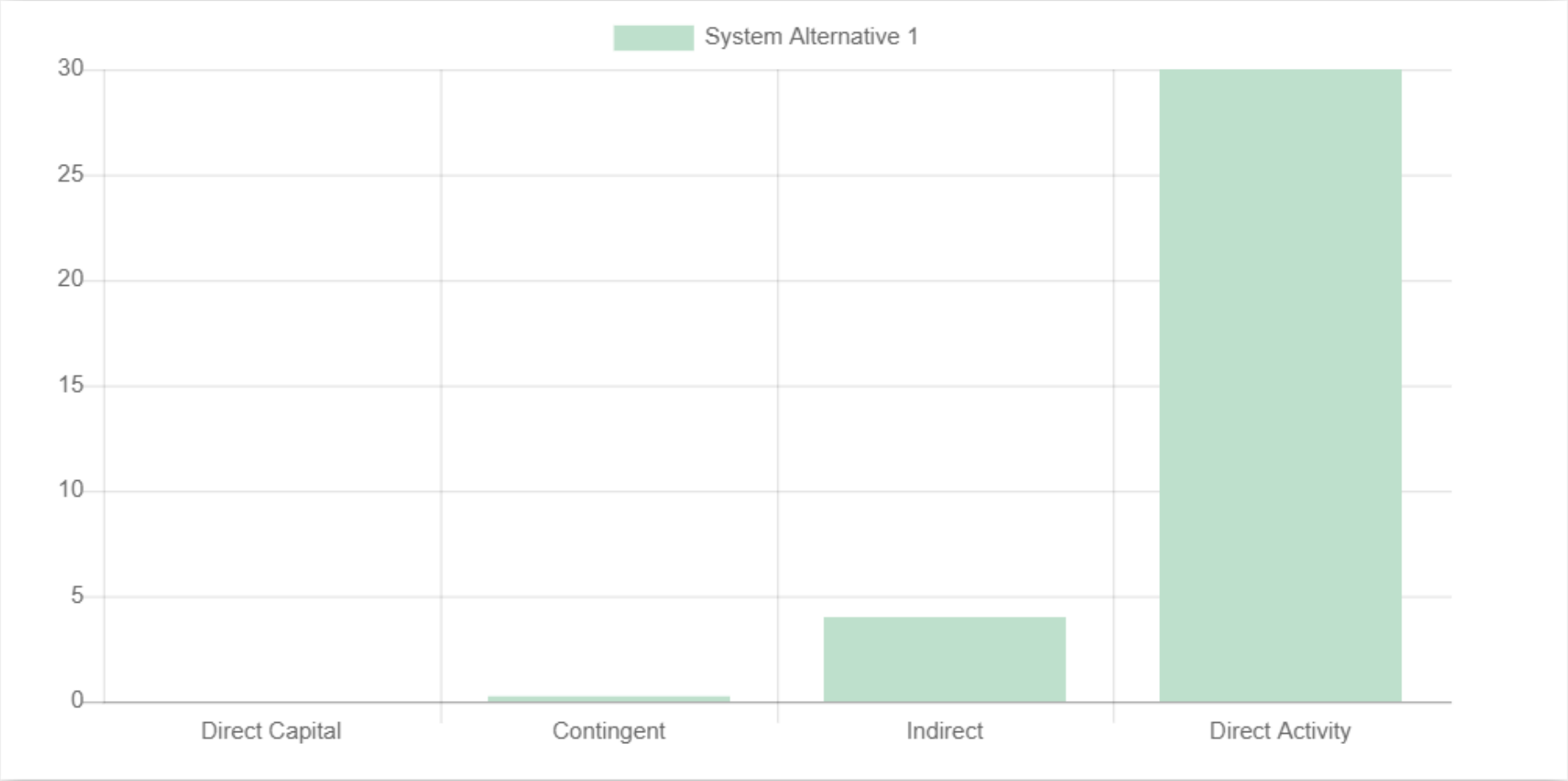
Example system: creating activities

- Product Alternative 1
  - In:
    - 5 kg PT_Lime
    - 40 kWhr PT_Electricity
    - 0.25 hrs PT_Labor
  - Out:
    - 1 item Product_1

Example System Results: External Costs



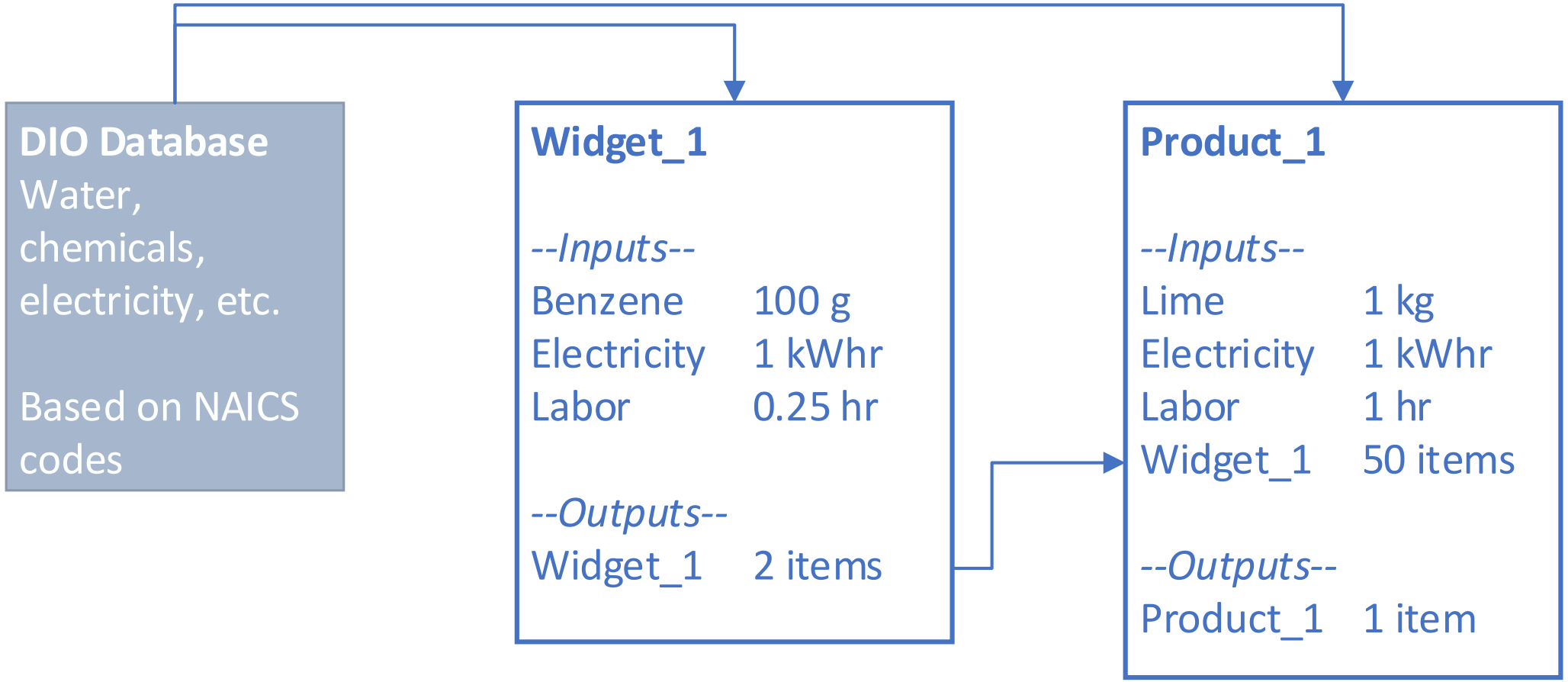
Example System Results: Life Cycle Costing



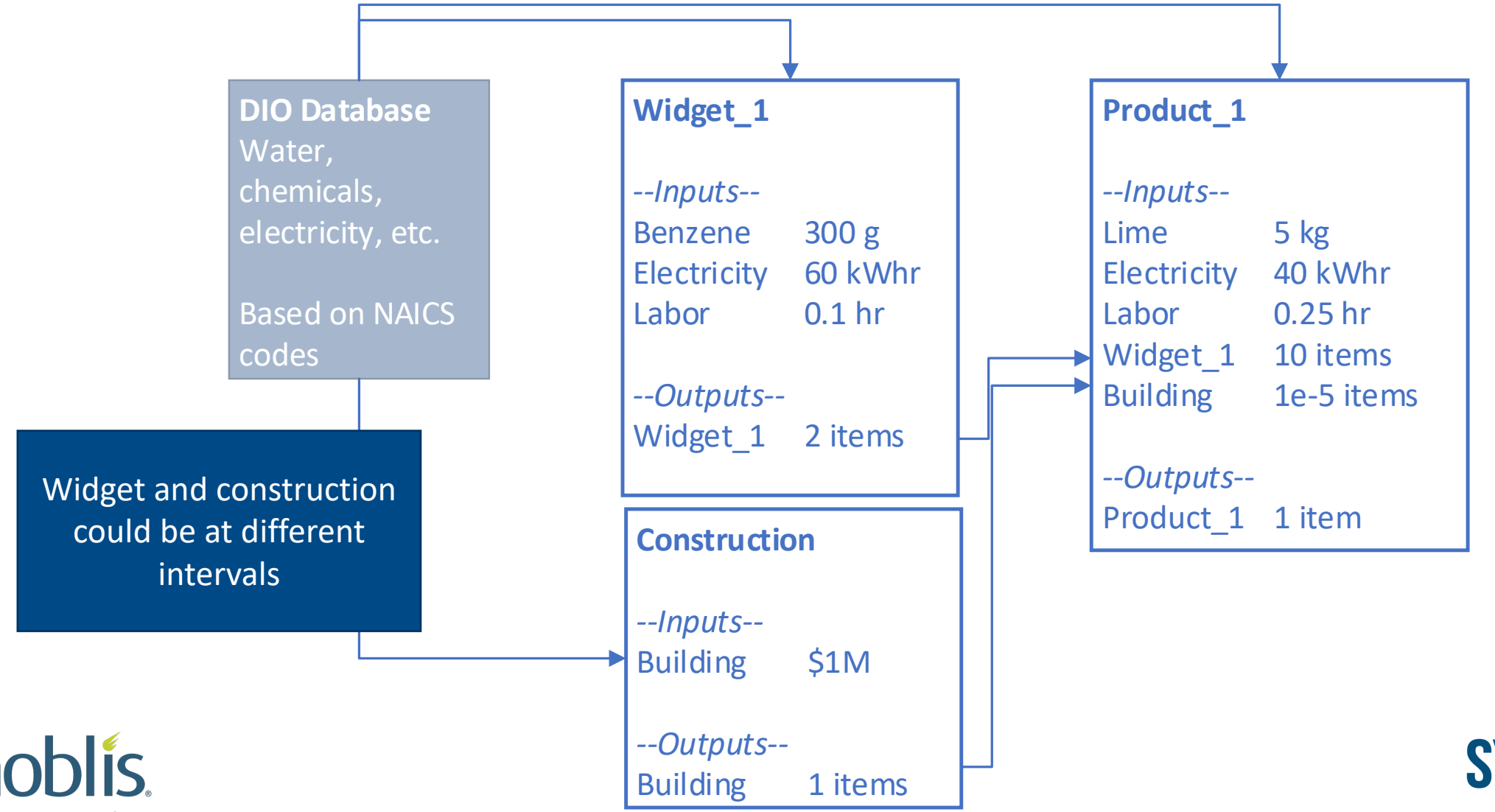
Web Tool Considerations

- Costs can be assigned to supporting activities or consuming activities.
  - E.g., we included a contingent cost on labor, but depending on system, we should include different contingent costs on the consuming activities
- We excluded waste generation. How would you add this?
- We excluded fugitive emissions. How would you add this?

Building on the Example System



Building on the Example System



Conclusions

- Costs for weapons systems are driven by O&S and liabilities (supply chain and ESOH)
- Costs need to be part of research and design (per DoD guidelines)
- Systematic and holistic cost assessment requires Sustainability Analysis
- Tools are available to facilitate these assessments:
  - DoD SA Guide
  - DoD Scoring Factors
  - SparkLC web tool
  - Open-source and paid software and databases

Benefits to DoD

- **The Sustainability Analysis approach, along with associated tools, aims to accomplish the following**
  - Improve affordability of weapons systems and platforms
  - Help researchers identify potential cost, supply chain, and ESOH issues

Discussion

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Funding acknowledgment: Noblis and SERDP-ESTCP

Additional Slides

Further Reading

- **Sustainability Analysis**
  - OASD 2016
- **LCA Overview**
  - Jolliet et al. 2004; Matthews et al. 2015; US EPA ORD et al. 2006; US EPA 2014
- **Impact Assessment**
  - Jolliet et al., 2003; Huijbregts et al. 2017
- **Monetization**
  - Weidema 2009

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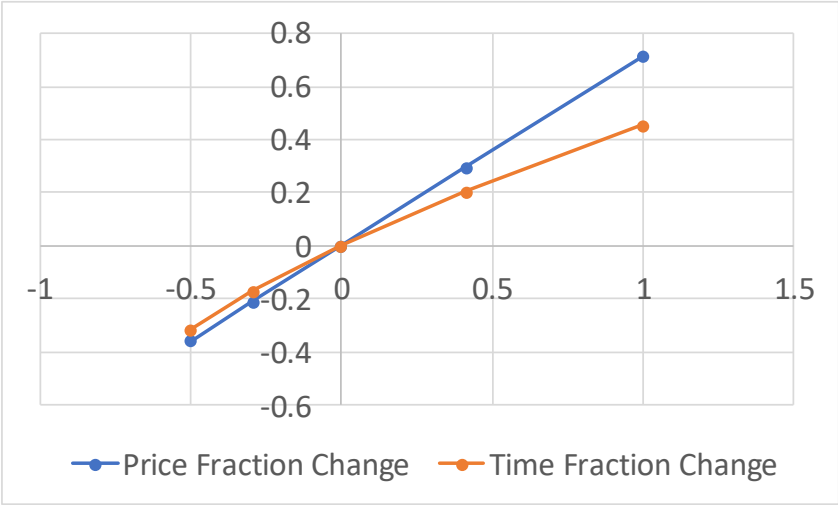
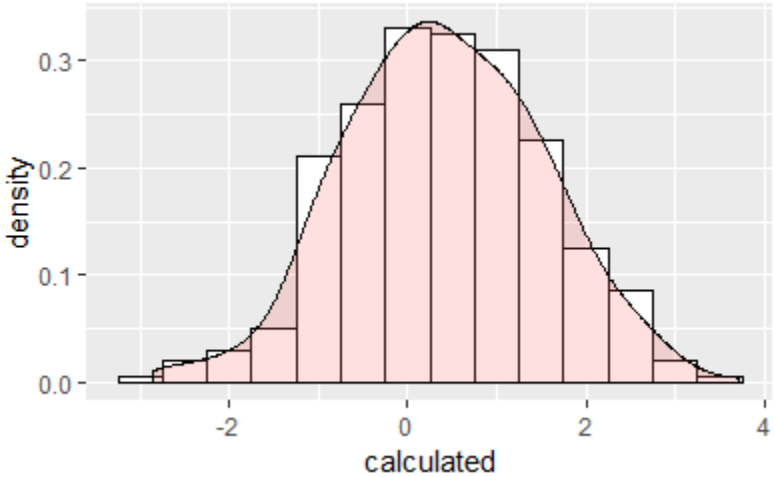
Uncertainty and Sensitivity

- **Engineering judgments, ranges with bounds are okay. Keep track of these estimates and decide if you need to revisit.**
  - As research matures, your data matures!
- **Various Approaches**
  - Low – Best – High estimates
  - Back of envelope sensitivity
  - Excel add-ins (@Risk, Crystal Ball)
  - “Homemade” tools in Matlab, Python, R, Excel





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