Advanced Materials and Manufacturing – the role of equipment design and modeling in smart manufacturing

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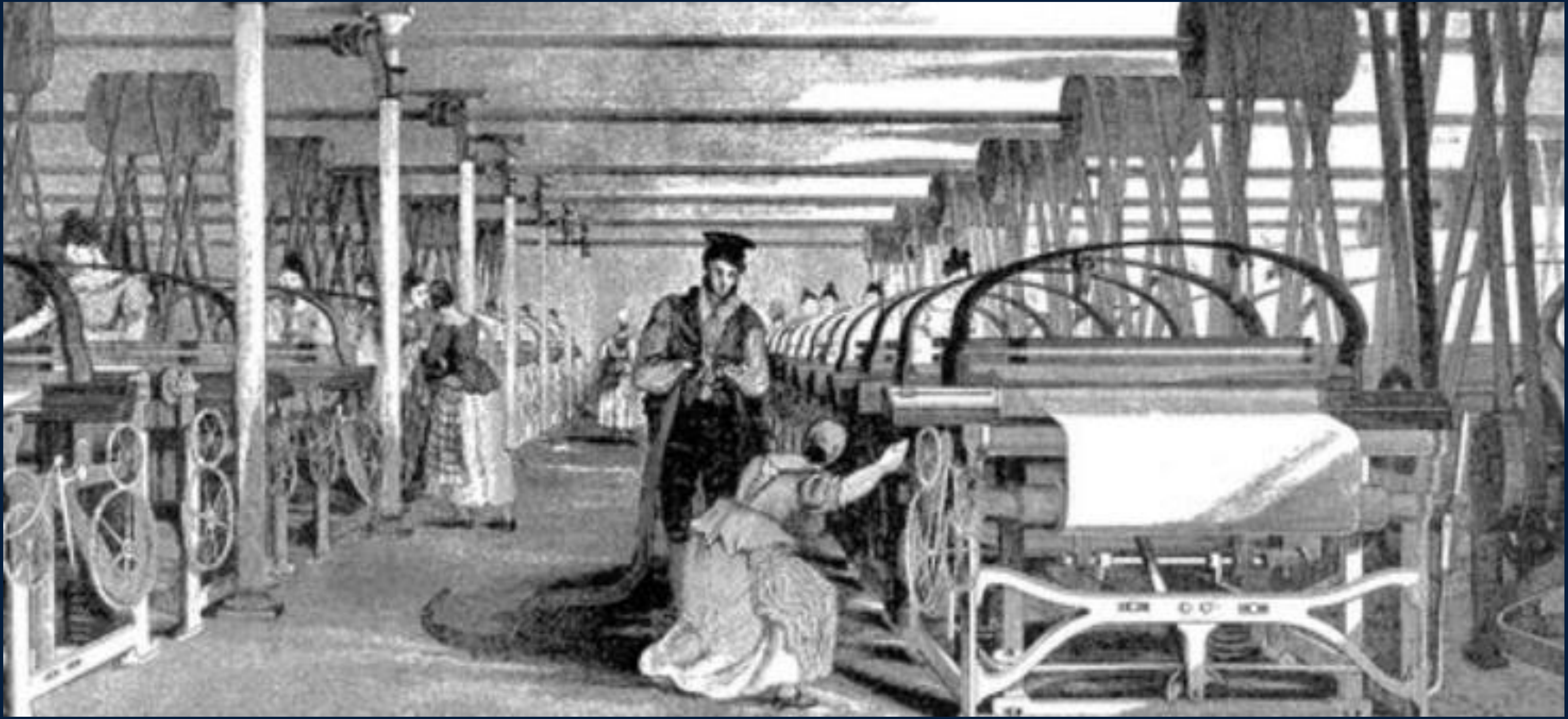
Applied Materials

Industrial Revolution: 1760 and evolving ever since!



Tenets of Manufacturing

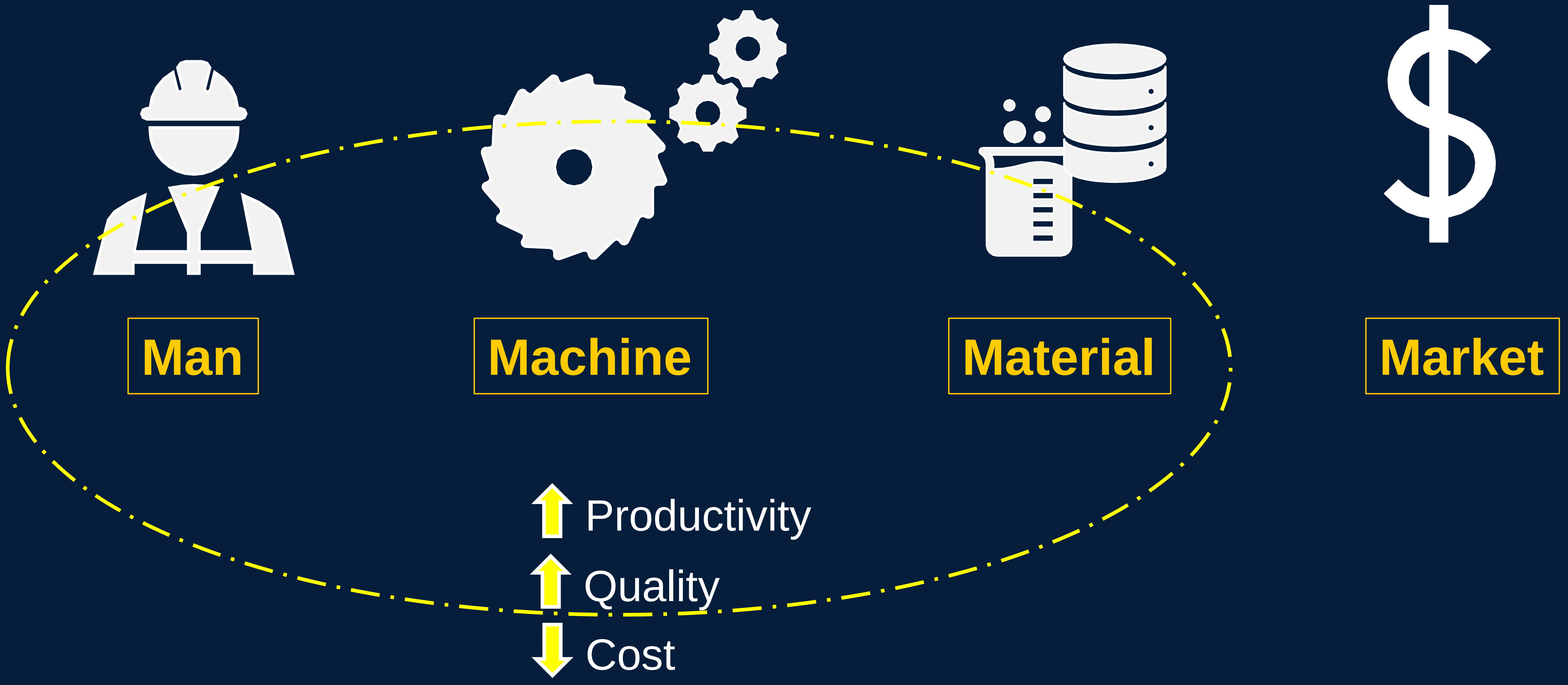
Man

Machine

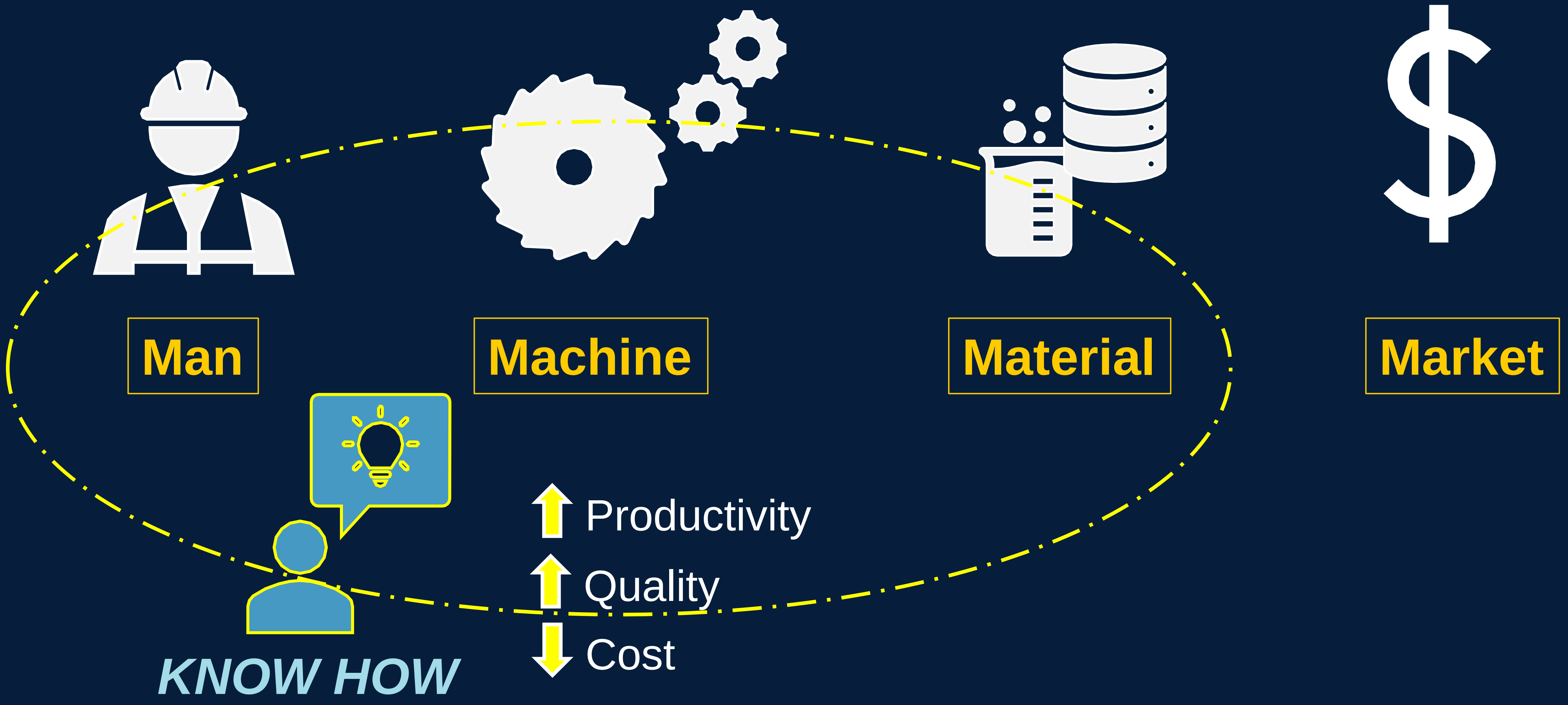
Material

Money

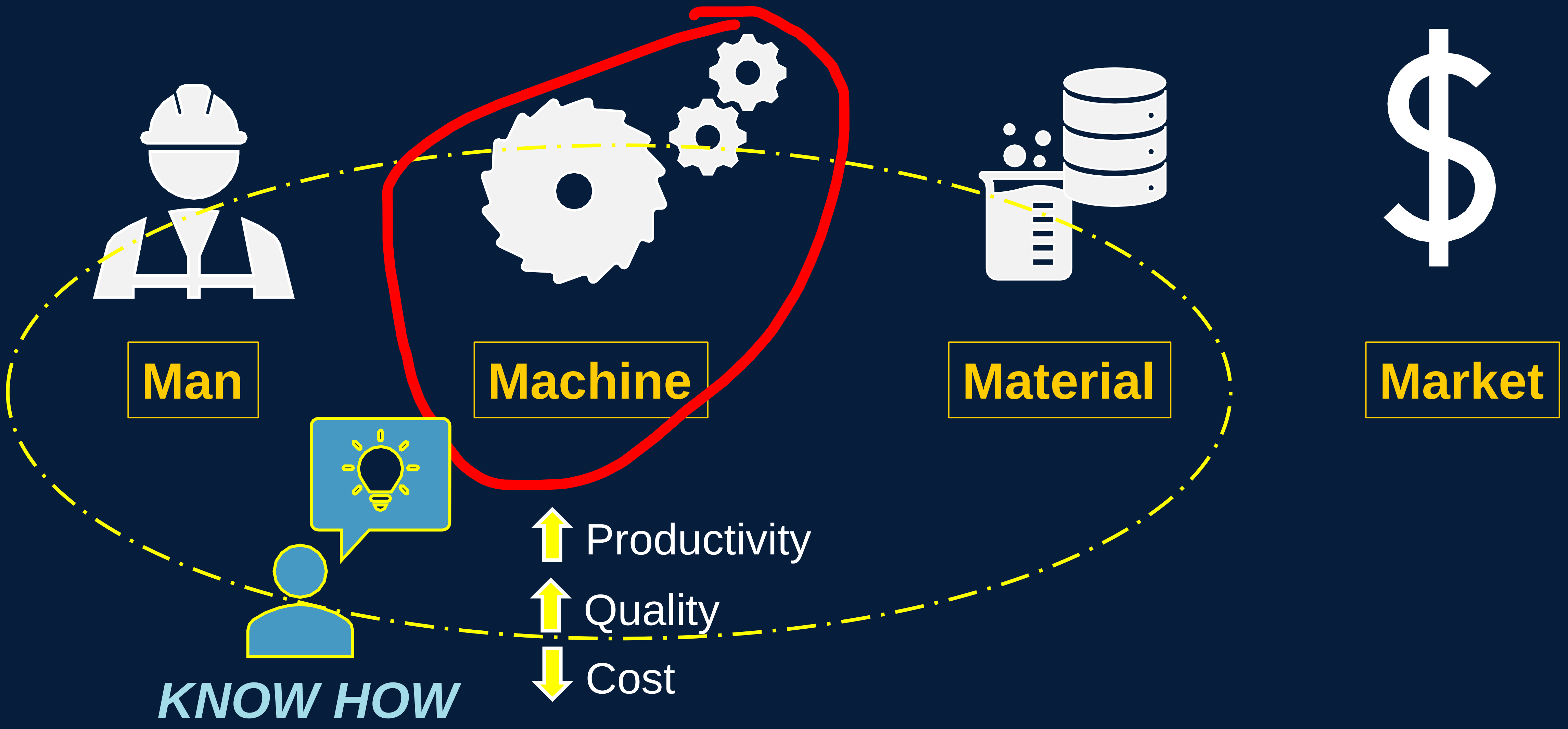
Tenets of Manufacturing



Tenets of Manufacturing

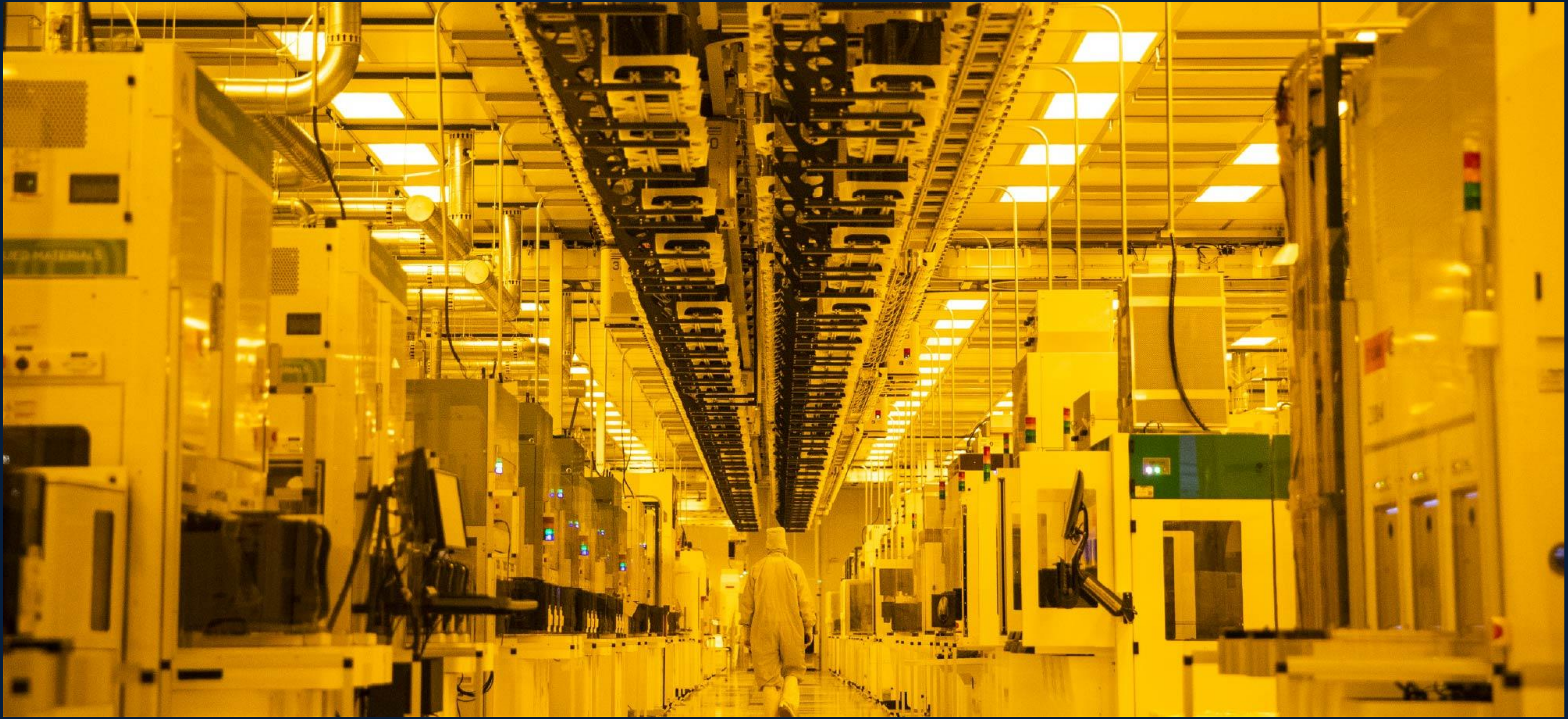


Tenets of Manufacturing



Beer Factory

Semiconductor Fab



ROM Manufacturing Comparison Summary

	Semiconductor	Crystalline Solar	Battery
Substrate	200 or 300mm wafer	5” or 6” inch wafer	1m roll
Units per hour	100s	1000s	10s
Number of Process steps	High 100s	10s	10s
Manufacturing Process	Batch/Cluster	Inline	Inline
Technology Complexity	High	Medium	Low
Material Handling	Pods to chips	Cassettes to Modules	Rolls to Packs
Facility	Class 1-10 Cleanroom	Class 10-100 Cleanroom	Dry-room
Equipment Line Cost	$Billion	$10s Million	$10 Million

Case Study: Solar Manufacturing

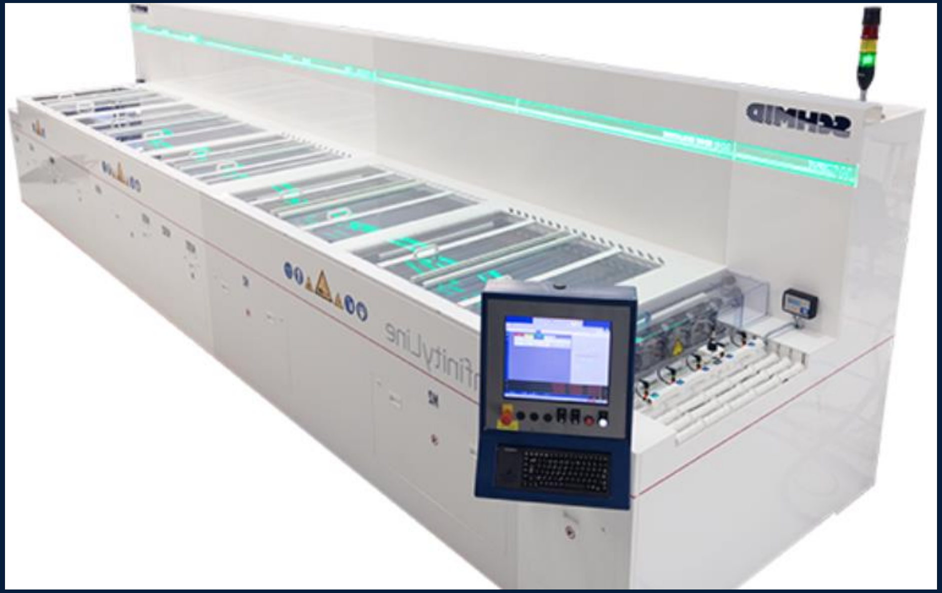
Cost of Solar: 1970 to 2020

Courtesy IEA

Solar Cell Manufacturing Line

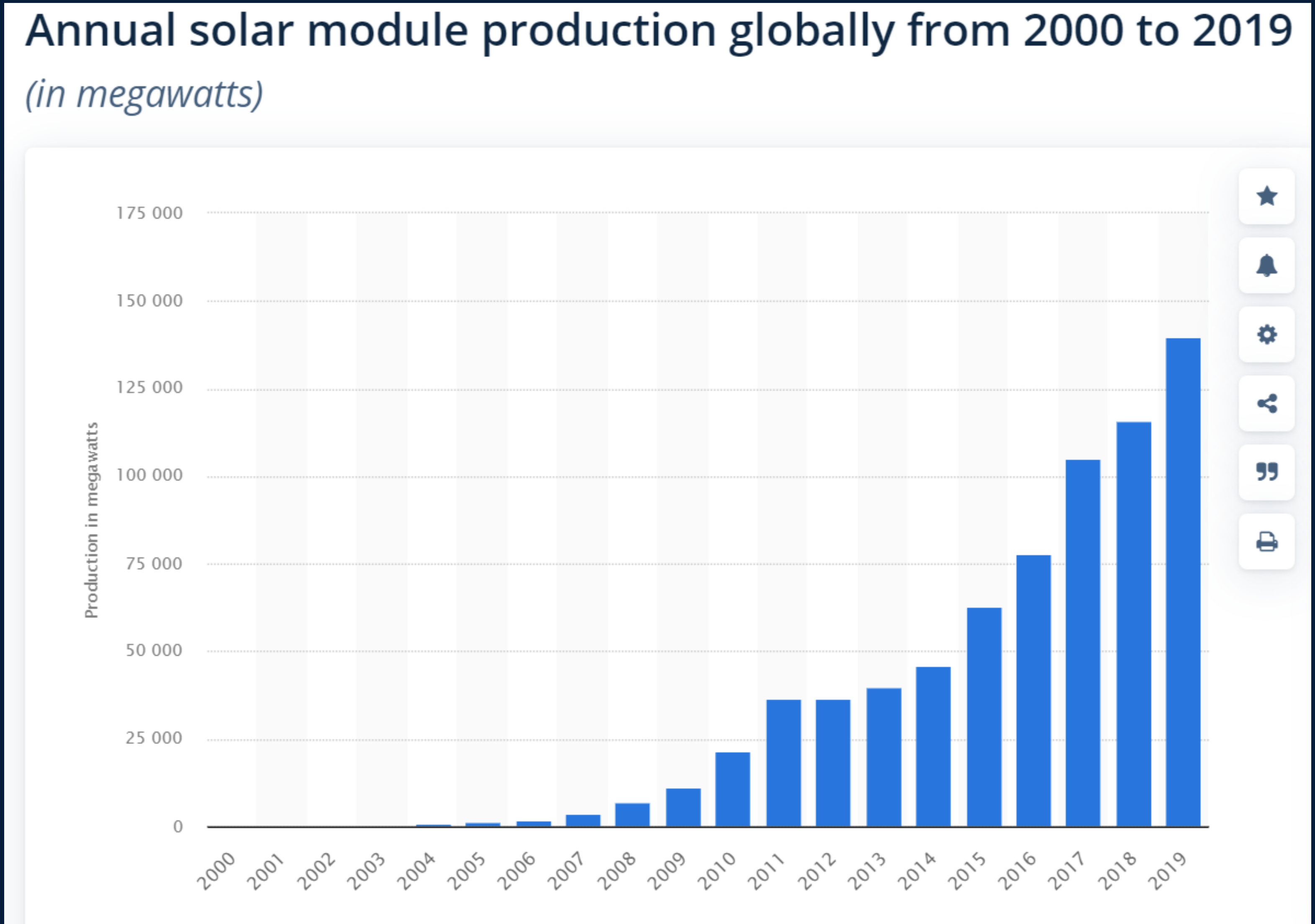
Scaling Photovoltaics: Wet tools in solar cell processing

- In-line processing instead of Batch processing
- Multi-lane processing: 1x → 5x →10x
- Faster processing times: agitation of chemicals, higher flows
- Less wafer breakage due to superior wafer transport through tools
- Higher yields: <50% to >95%+ due to better equipment controls



Courtesy Schmid Technologies

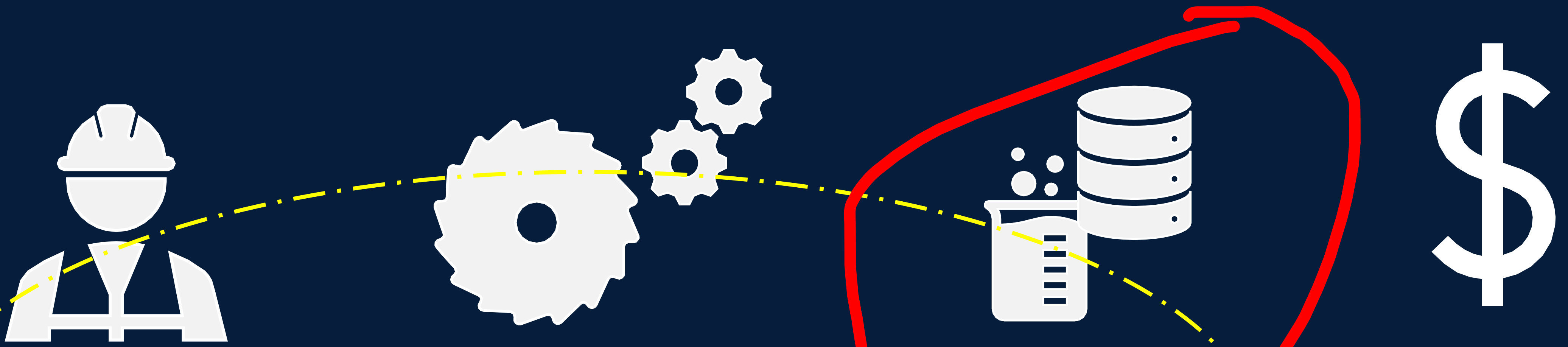
Global production of solar modules



Courtesy Statista

Innovation in manufacturing equipment for solar cell and module production enabled the massive increase in production of solar modules.

Tenets of Manufacturing



Man

Machine

Material

Market

↑ Productivity

↑ Quality

↓ Cost

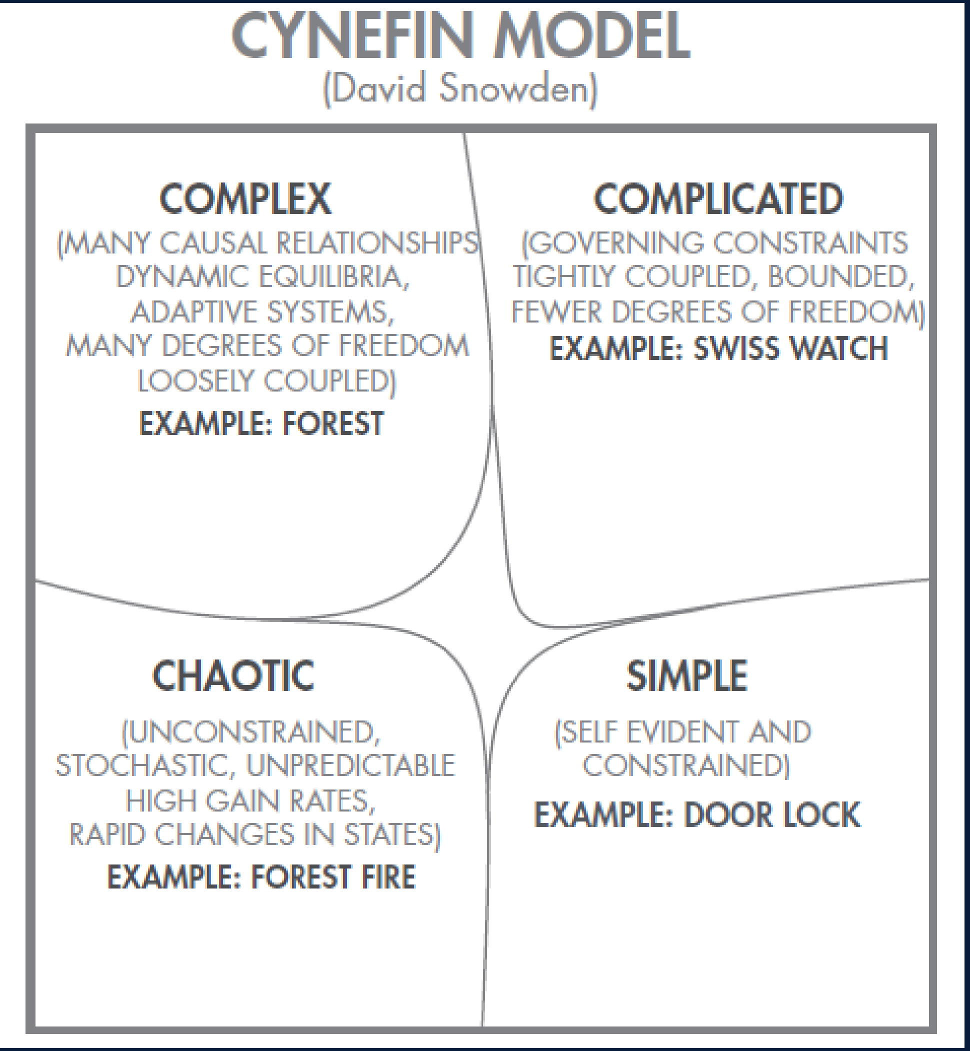
Semiconductor Materials Exploration Over Time

- Explosion of new materials in ~2000's
- Recent focus on structure-property relationships
  - Effect of thin film, interfaces, dopant/implant diffusion, 2D, grain boundaries, etc.

Ack: S. Shankar (Intel)

Cynefin Model

Manufacturing issues are moving from being complicated to complex
→ loosely coupled



Therefore, problems are becoming less deterministic and more probabilistic
→ modeling is critical in informing a direction and/or helping to make a decision

Modeling From Circuits to Chambers to Films to Atoms

In-house semi EDA (Electronic Design Automation) spin-out as companies

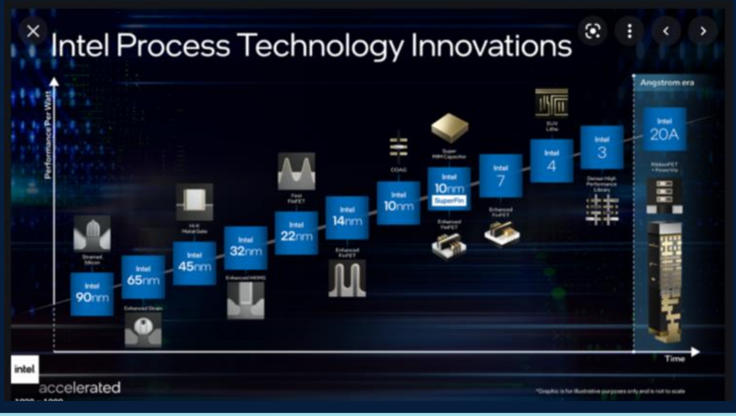
TCAD models forming *(process and device models)*

Independent semi TCAD organizations form + design teams flourish

Process, device, thermo-mechanical, plasma, lithography, and chamber teams form and grow within TCAD

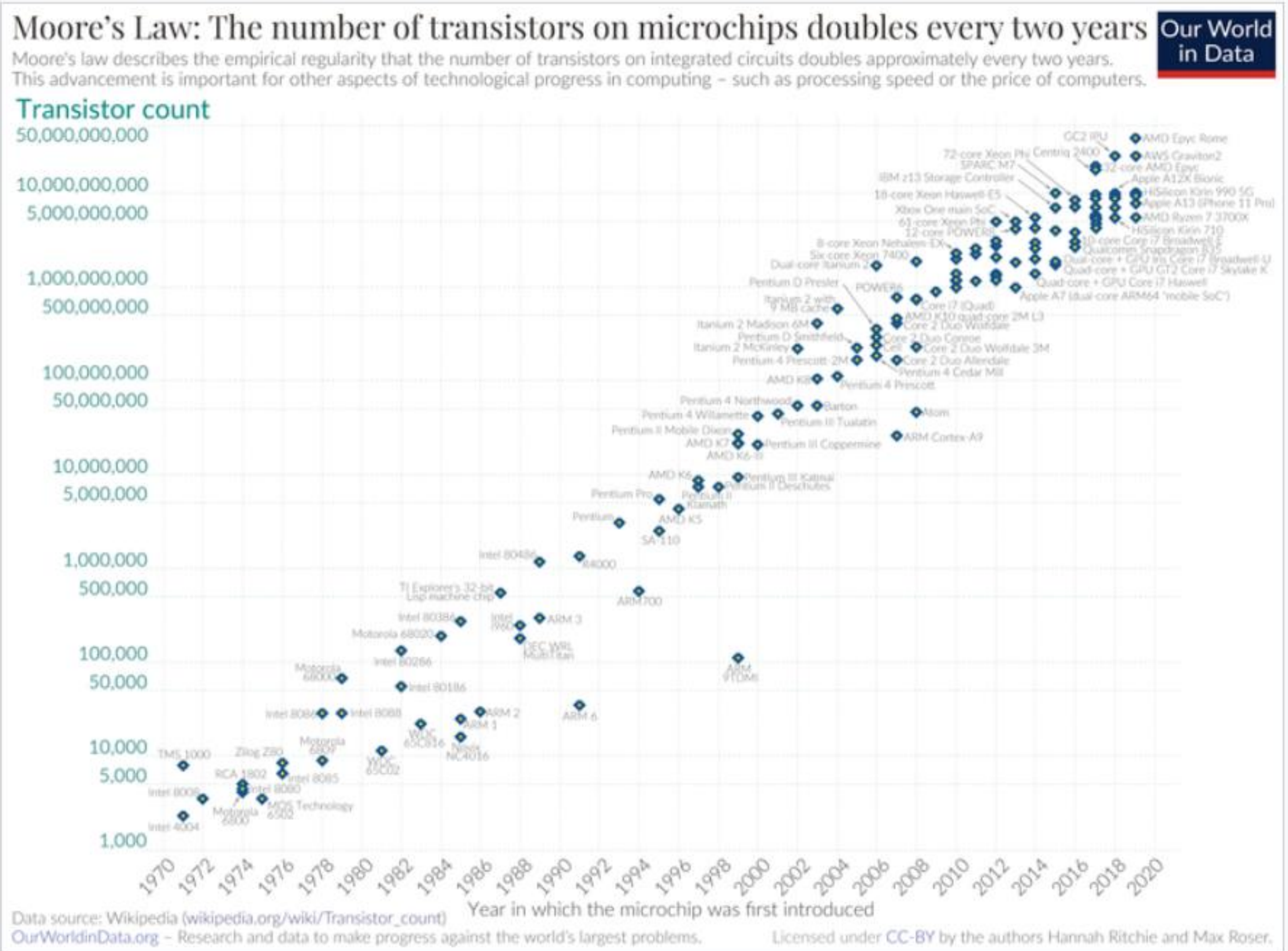
Ab-initio materials and chemistry exploration outgrowth of TCAD process, fluid, chamber groups + nascent design-technology co-optimization efforts begin

1980 | 1990 | 2000 | 2010 | 2020



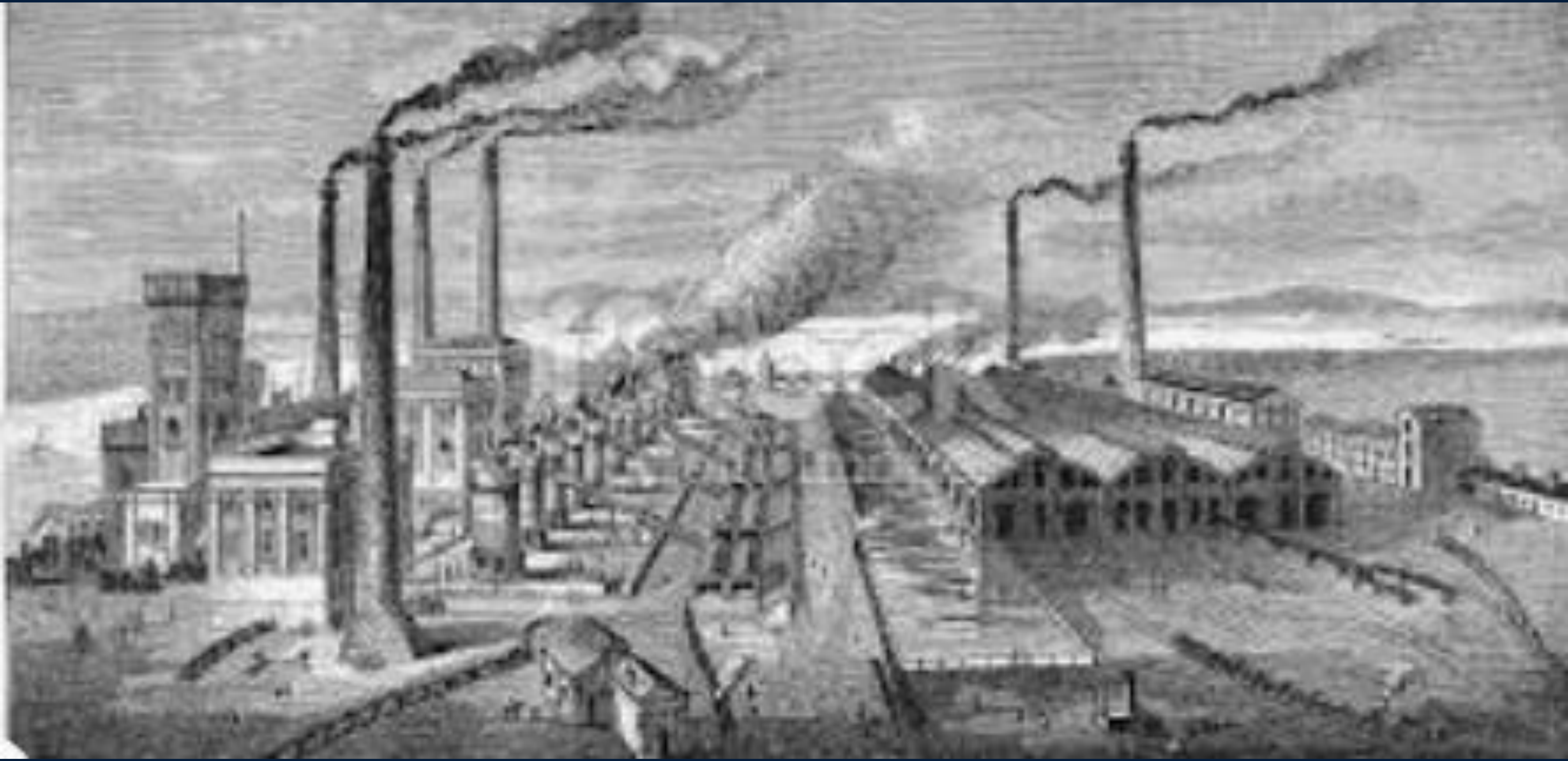
TODAY: Mature TCAD and design organizations try to leverage/ collaborate for co-optimization, develop digital-twins, and atomic-scale models becomes critical

Moore’s Law



A semi-log plot of transistor counts for microprocessors against dates of introduction, nearly doubling every two years.

So, what now?



Power consumption for 100K Wafer Start Fab

~ 1 TW-h/year

Make Possible A Better Future Vision

3 X 30 GOAL

↓30% Equivalent Energy

↓30% Chemical Consumption

↓30% Cleanroom sq. ft. / wafer

by 2030

1x
OUR IMPACT

100x
INDUSTRY'S IMPACT

10,000x
IMPACT ON THE WORLD

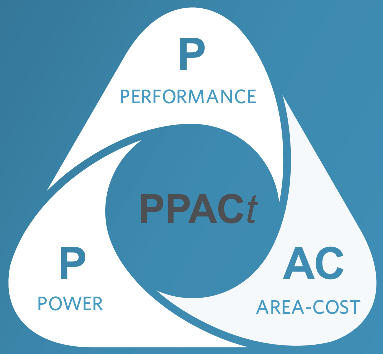
100% renewable energy by 2030

50% reduction in CO_2 emissions by 2030

COI Culture Of Inclusion

ecoUP — **Upgrades, Products and Services**

SuCCESS 2030 — **Supply Chain Sustainability Certification**



Sustainable AI and Electronics

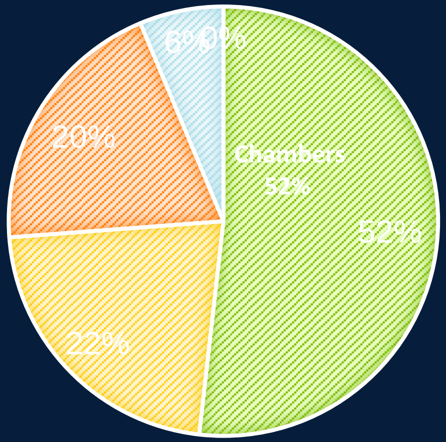
Energy Modeling of Fab Tool

Chamber parts
(ex:plasma source energy usage)

System components
(ex:robot energy usage)

~1M kWHr/Year

Support tools
(ex: pump energy usage)

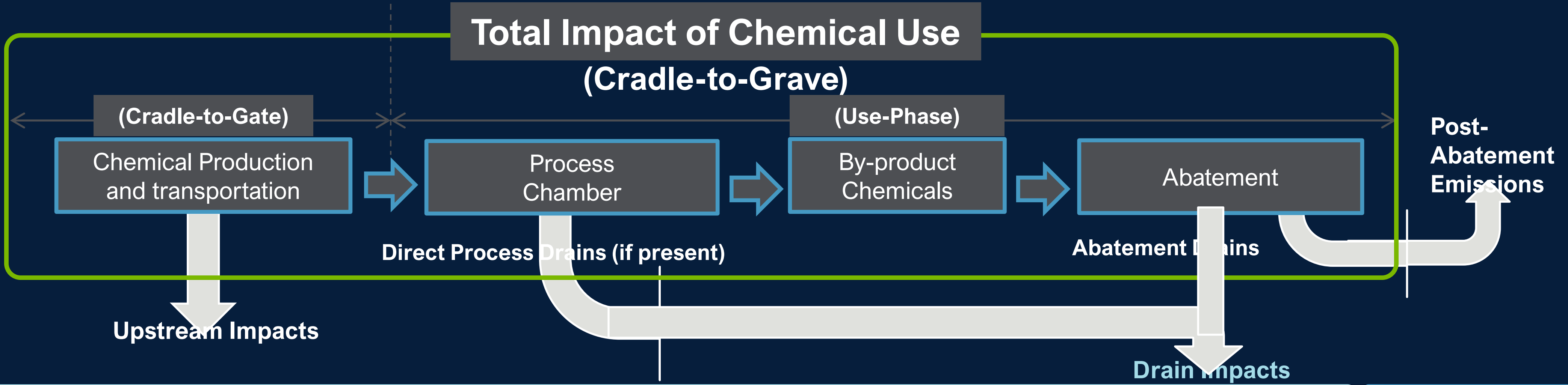


3x30 Chemical Impact

- Life-cycle inventory (LCI) data will capture upstream impact extraction/refining/transportation
- DFE model captures use-phase GHG generation, water consumption, and waste generation

Cradle to Grave chemical use impact measured in g CO_2 eq.

	(Cradle-to-Gate)	(Use-Phase)
Primary Reporting Metric	CO_2 LCI Data	Chamber emissions, post-abatement
Data collected for future use	H_2O LCI Data	H_2O consumption, per DFE Model
		Waste generated, per DFE Model



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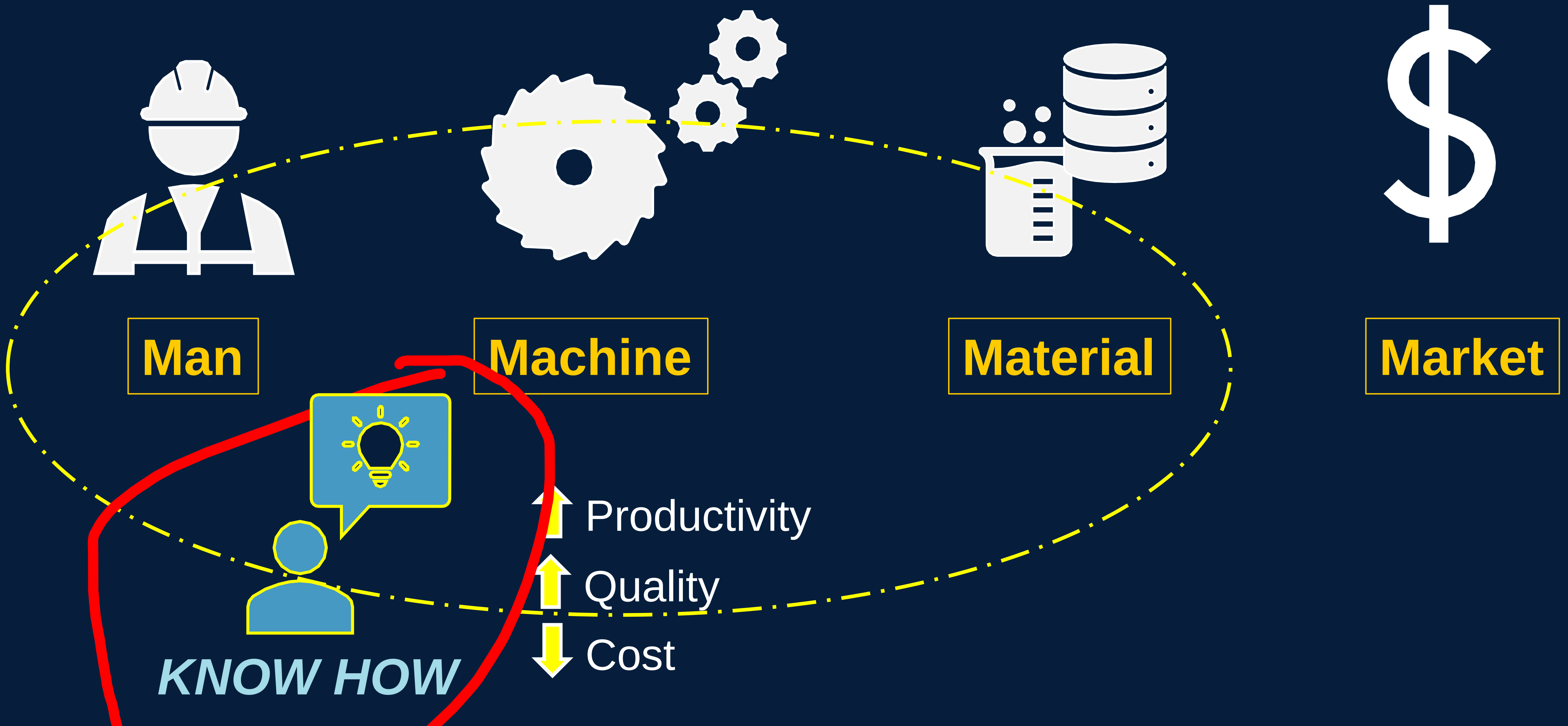


MAKE POSSIBLE
A BETTER FUTURE

Q&A