umerc + METS

Value Metrics and Global Impact Potential of Wave Energy

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Motivation: design convergence, strategic impact

- Design convergence is necessary for wave energy to achieve impact on a climate-relevant magnitude and timescale
- R&D in the next decade must strategically and systematically consider global impact to ensure effort aligns with intent

Questions we want to answer

Ultimate question:

What **designs** should the wave energy community converge to, and what is the most effective **R&D pathway** to get there?

Interim question:

What **metrics** should we use to evaluate different designs and R&D priorities? How do different **markets** influence the selection of designs and R&D priorities?

Metrics and Markets

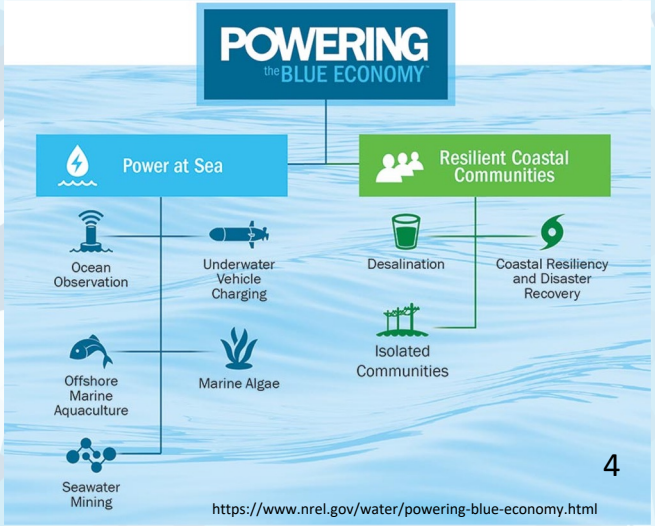
Metrics

- Consider environmental, social, economic impacts (triple bottom line)

https://sustain.wisconsin.edu/sustainability/triple-bottom-line/

Markets

- How do value metrics for PBE markets compare to those for utility markets?
- Will design convergence optimized for PBE markets result in a suitable design for utility markets?



https://www.nrel.gov/water/powering-blue-economy.html

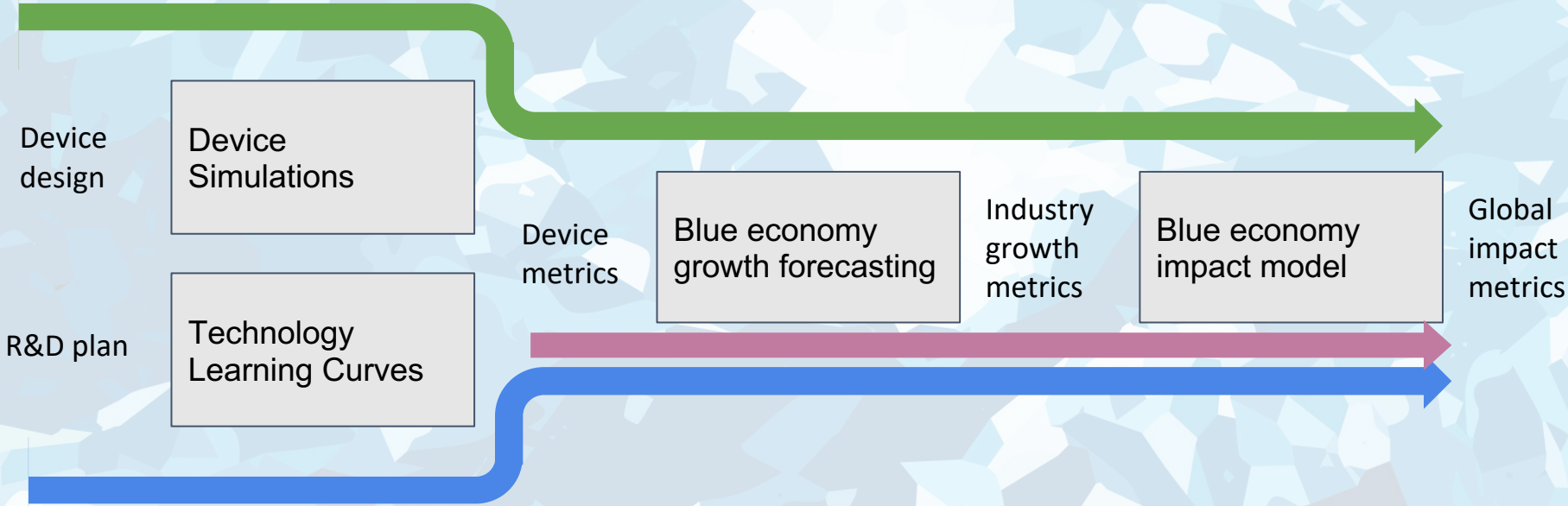
Types of Metrics

Good optimization metrics are independent, measurable, predictive, relevant

		Economic	Environmental	Social
Leading	Exploration stage: proxies	ACE = ACCW / CCE [m/$]	Marine operations [#/yr]	Energy equity program funds [$]
Leading	Project stage: metrics	LCOE [$/kWh]	Global warming potential [kg CO2e / kWh]	Energy projects in low-income areas [#]
Lagging	Monitoring stage: indicators	Energy price [$/kWh]	Atmospheric CO2 concentration [ppm]	Energy disparities by income [%]

Proposed Framework

Use Cases of Framework



1. Evaluate designs
2. Evaluate R&D plans
3. Evaluate markets

Inputs and Outputs of Framework

Operating principle, control scheme, geometry, PTO, …

Device design

Device Simulations

R&D plan

Technology Learning Curves

$ for each device metric

Device metrics

LCOE, LCOX, LVOE, NVOE, profitability, payback period, non-energy value, NPV, ACE, EROI, ecological footprint, GWP, …

Blue economy growth forecasting

Industry growth metrics

devices deployed in each market

Blue economy impact model

Global impact metrics

UN SDG indicators

Legatum prosperity index

Gross national happiness

[1] Mai, Trieu, Matthew Mowers, and Kelly Eurek. 2021. Competitiveness Metrics for Electricity System Technologies. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-72549. https://www.nrel.gov/docs/fy21osti/72549.pdf.

[2] Scott Jenne. Economics of Marine Renewable Energy Systems. 3rd Annual Ocean Energy Conference, UMass Dartmouth. https://www.nrel.gov/docs/fy21osti/78328.pdf.

Wave Energy Value Proposition

Temporal

- Seasonal variation
- Overall variation

Spatial

- Proximity to population centers
- Proximity to offshore blue economy devices

-ilities

- Flexibility
- Reliability
- Resilience

Functional

- Wave environment damping

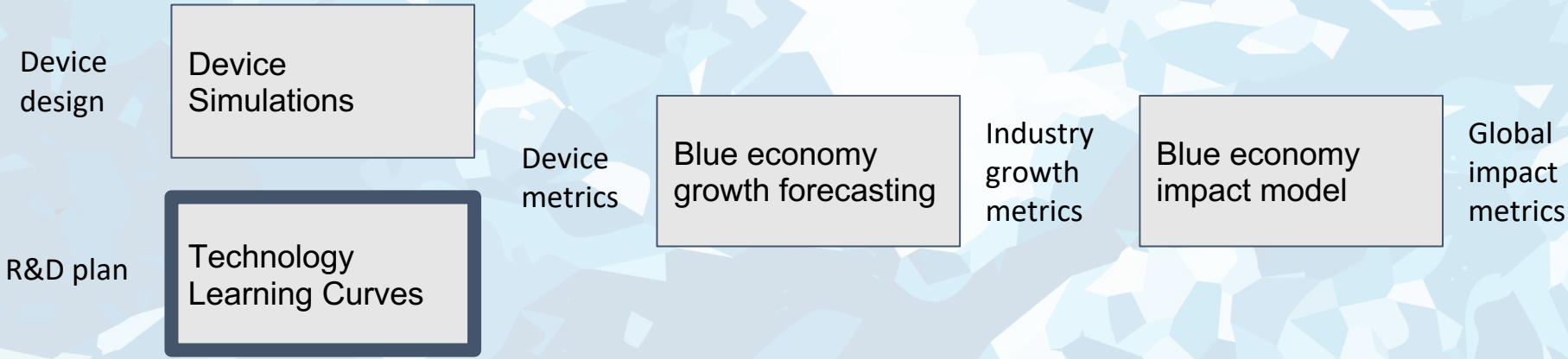
Device Simulation Module

Engineering simulations (Waves-to-wire, multidisciplinary, cost modeling)

Product family and platform design

Life cycle analysis

Technology Learning Curve Module



Technology roadmapping

Parameter sensitivities from device simulation module

Blue Economy Growth Module

Device design

Device Simulations

R&D plan

Technology Learning Curves

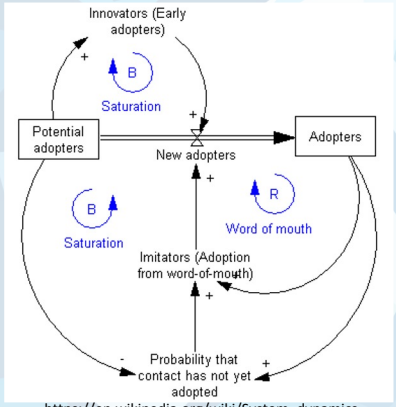
Device metrics

Blue economy growth forecasting

Industry growth metrics

Blue economy impact model

Global impact metrics



https://en.wikipedia.org/wiki/System_dynamics

Linearized model likely misleading

System dynamics

Macroeconomics

Blue Economy Impact Module

Predictive Impact Modeling

Social Life Cycle Analysis

Potential Future Work

- Further develop value metrics and requirements for PBE markets
- Evaluate metric suite for independence and similarity across markets
- Implement modules (likely bottleneck: blue economy growth forecasting)
- Use optimization to find design family and research priorities
- Complete sensitivity study and use results to inform industry trajectory

Questions for Discussion

What challenges do you see in the implementation and application of this framework?

Can the framework be simplified while remaining meaningful? Must more complexity be added before the framework is representative?

What other methods can be leveraged to improve the framework?

How can we encourage researchers to consider the systemic impact of their work and prioritize strategically?

Thank You

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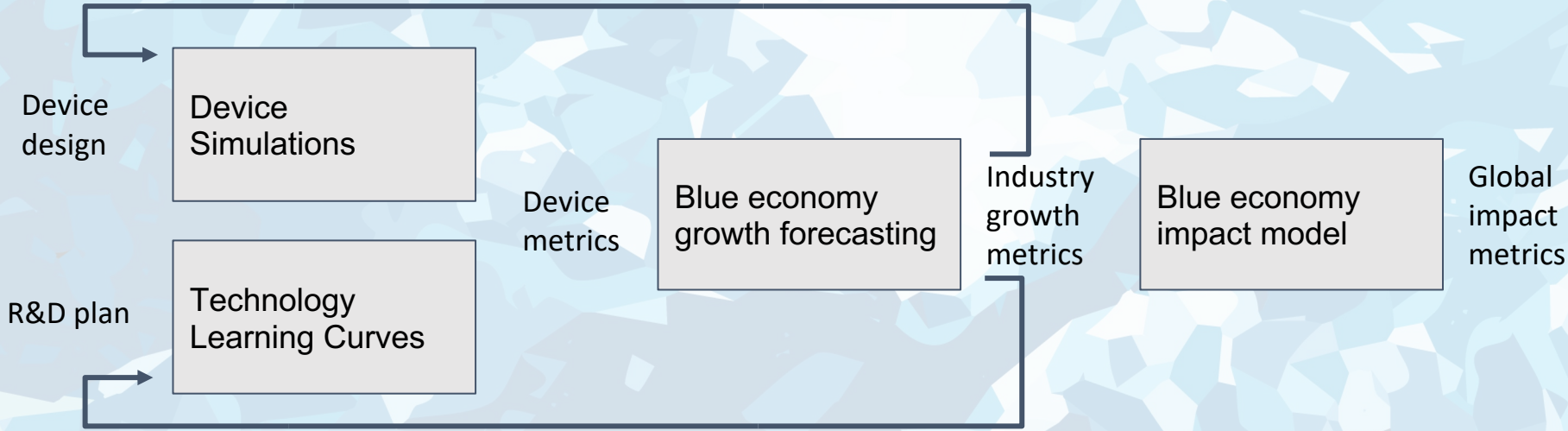
Potential Challenge: Feedback?



Industry growth affects economies of scale

Feedback can likely be eliminated/mitigated with careful module scoping