

Workshop on Widening
Access to TinyML Network by
Establishing Best Practices in
Education



3 - 7 July 2023
An ICTP Meeting
Trieste, Italy

Further information:
<http://indico.ictp.it/event/10185/>
smr3851@ictp.it

Responsible AI via Sustainable and Privacy Preserving EdgeML



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How can we adapt our approach to EdgeML to support **Responsible AI** future?

A voice command starts your TV's recognition, and viewing data is interconnectivity has privacy implications. smart TV spying and how to stop it.

How to Stop Your Smart TV From Spying on You

FBI warns about snoopy smart TV

FBI warns about snoopy smart TV

AI is harming our planet: addressing AI's staggering energy cost

Tue, May 24, 2022

The Observer Smart homes
How to stop your smart home spying on you

Everything in your smart home, from the lightbulbs to the

WILL KNIGHT BUSINESS JAN 21, 2020 7:00 AM

AI Can Do Great Things—if It Doesn't Burn the Planet

The computing power required for AI landmarks, such as recognizing images and defeating humans at Go, increased 300,000-fold from 2012 to 2018.

FORBES > INNOVATION > AI

Deep Learning's Carbon Emissions Problem

Rob Toews Contributor I write about the big picture of artificial intelligence.

Jun 17, 2020, 11:54am EDT

Follow

Listen to article 13 minutes

This article is more than 3 years old.

2

Responsible AI via Sustainable and Privacy Preserving EdgeML

1. What is a (**Datasheet** for a) Machine Learning Sensor?
2. **Applications** of TinyML for Sustainability
3. Environmental Footprint of **TinyML Systems at Deployed Scale**

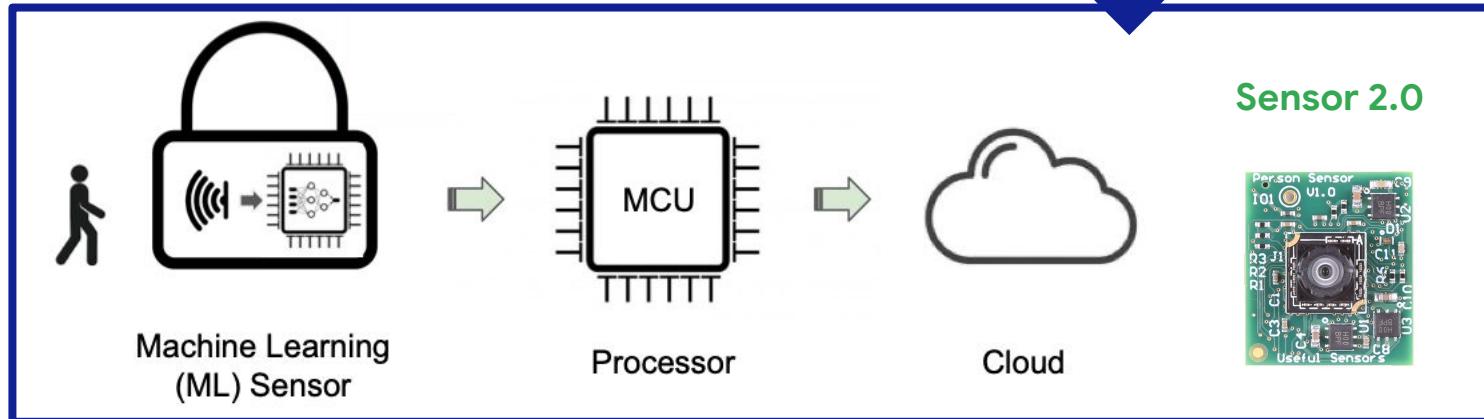
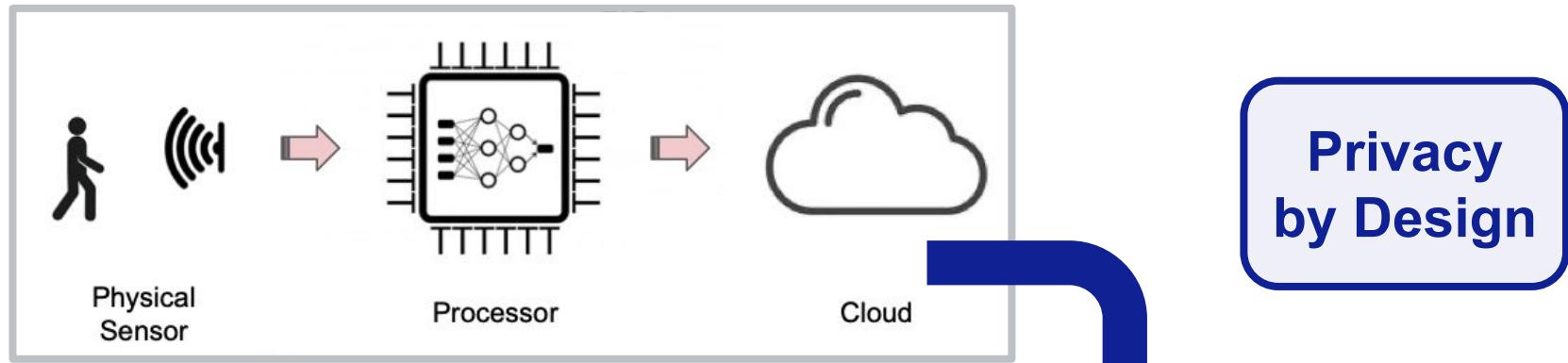
Our Suggested Transparent Paradigm

Positive Effects of TinyML

Environmental Footprint at Scale

What is a (Datasheet for a) Machine Learning Sensor?

What is a Machine Learning Sensor?



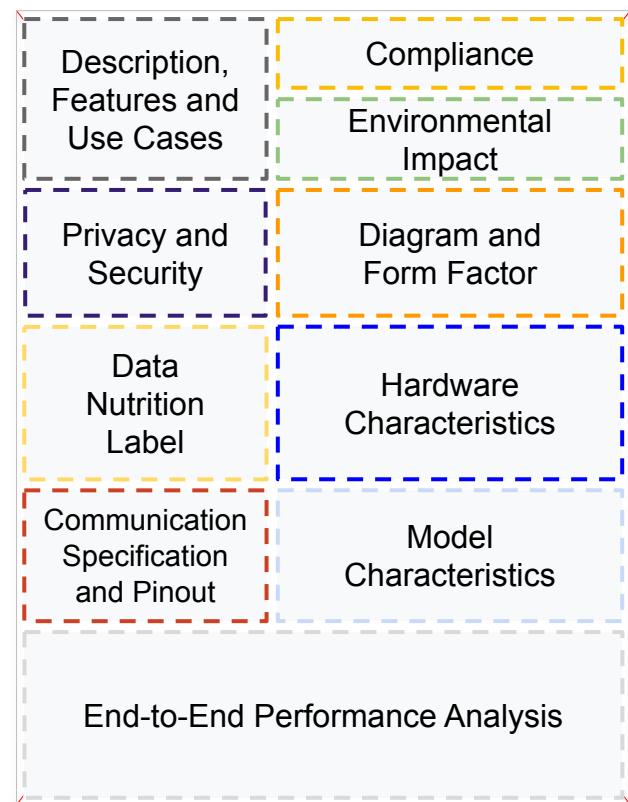
We suggest **transparency** as a core value to overcome these challenges.

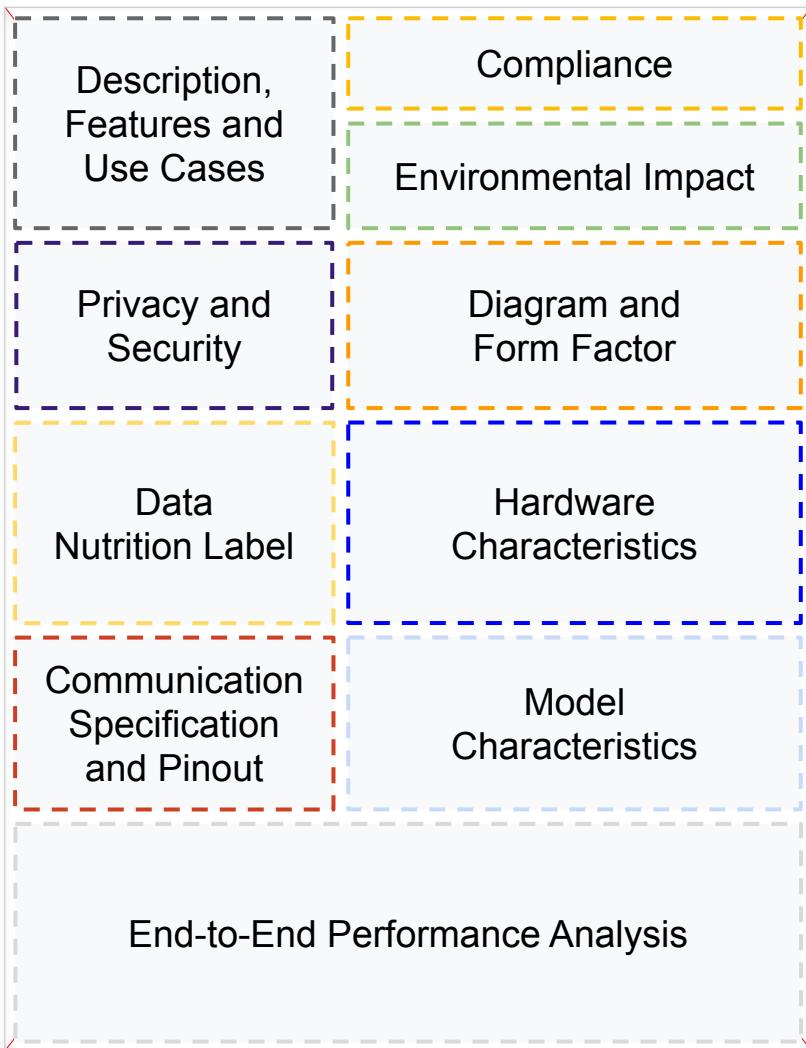
Datasheets for Machine Learning Sensors

Matthew Stewart^{1*} Pete Warden^{2,5} Yasmine Omri¹ Shvetank Prakash¹ Joao Santos¹
Shawn Hymel⁴ Benjamin Brown¹ Jim MacArthur¹ Nat Jeffries⁵ Brian Plancher³
Vijay Janapa Reddi¹

¹Harvard University ²Stanford University ³Barnard College, Columbia University
⁴Edge Impulse ⁵Useful Sensors

arxiv.org/abs/2306.08848

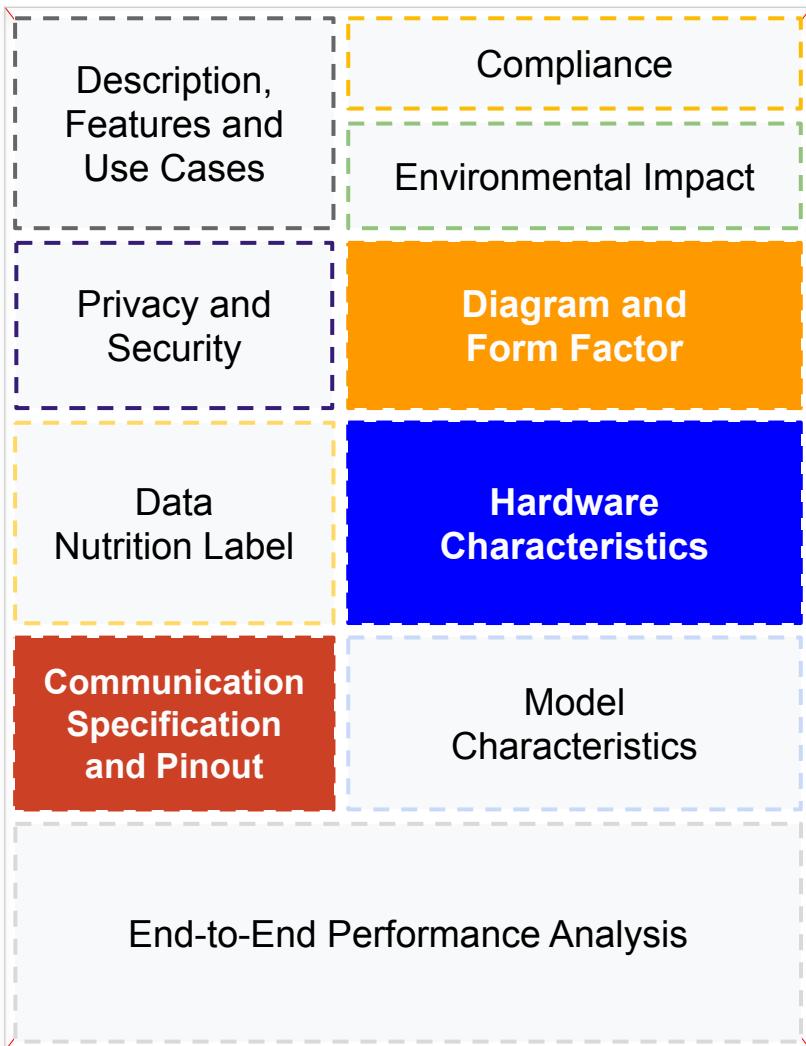




ML Sensor Datasheets

Have 3 Goals:

1. Raise the level of **abstraction**
2. Transparent at the **hardware, data, model, and end-to-end layers**
3. Support **Responsible** Use

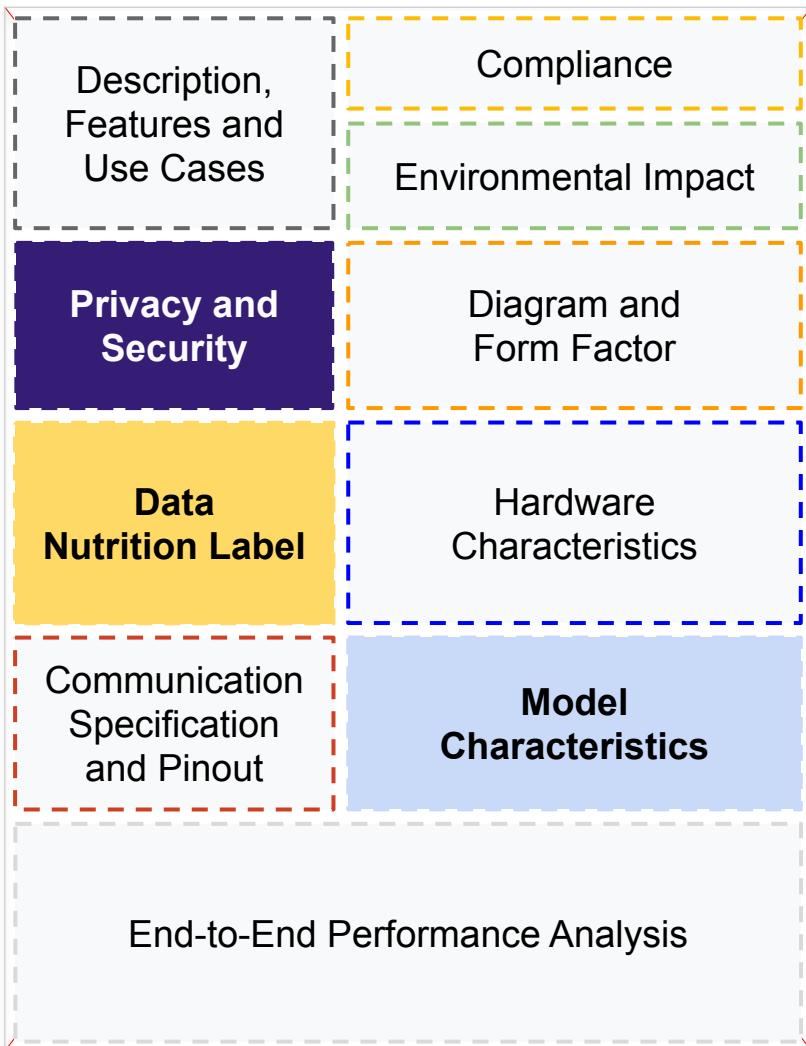


ML Sensor Datasheets

Have 3 Goals:

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3. Support Responsible Use

Standard Sensor
Datasheet



ML Sensor Datasheets

Have 3 Goals:

1. Raise the level of abstraction
2. Transparent at the hardware, **data, model**, and end-to-end layers
3. Support **Responsible** Use

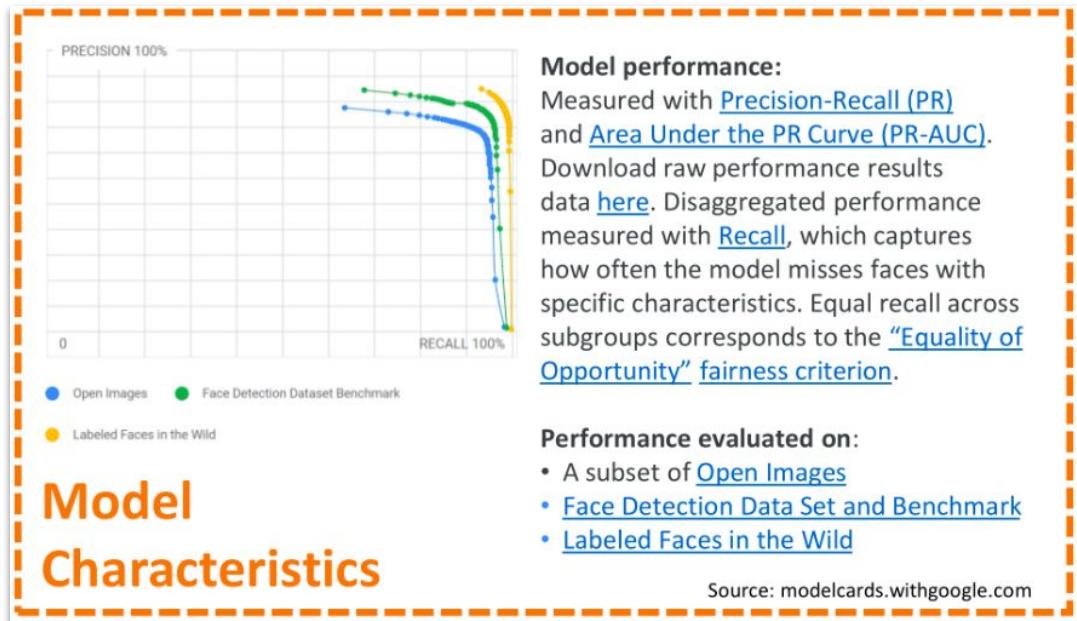
**Responsible
Machine Learning
Analysis**

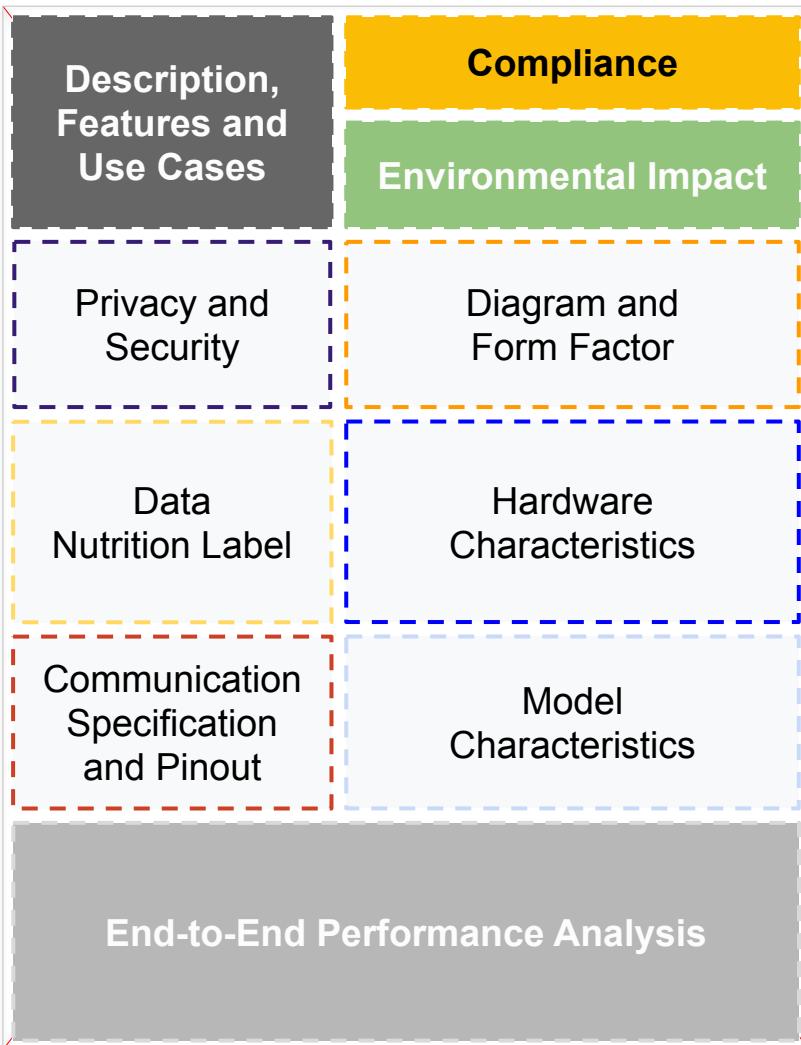
Responsible Machine Learning Analysis

Source: datanutrition.org

Aggregated Human Data Quality Review Ethical Review About Humans
Commercial License Multi-source Funded Not Actively Updated Multi-source Data
No Subpopulations

Dataset Nutrition Label



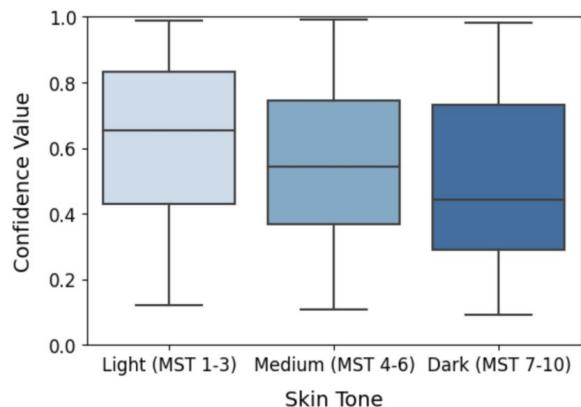
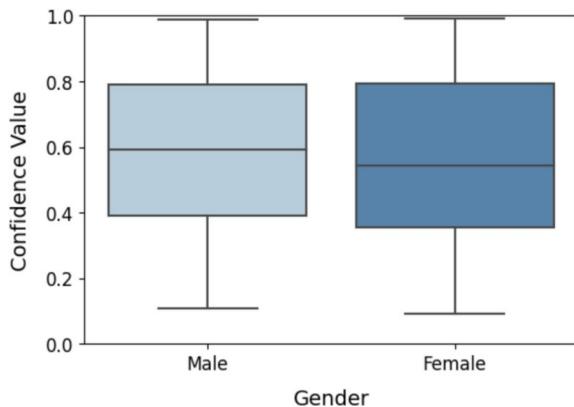
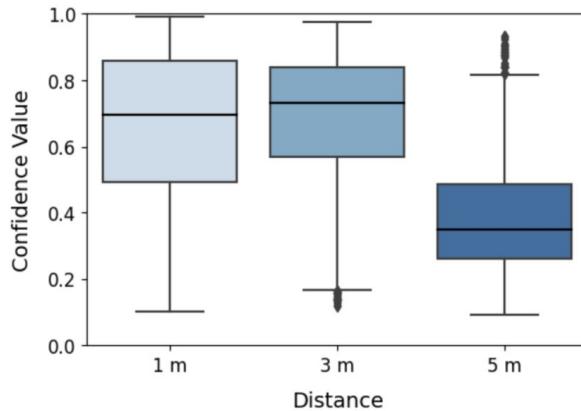
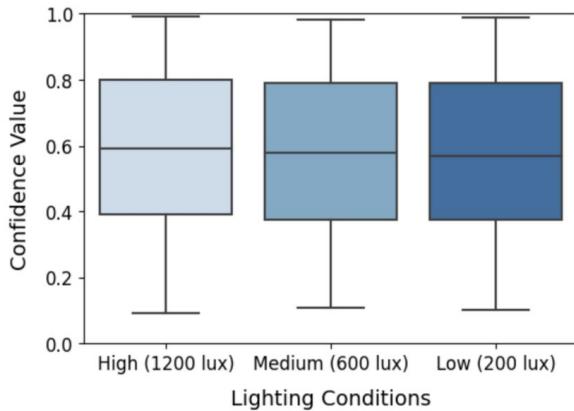


ML Sensor Datasheets

Have 3 Goals:

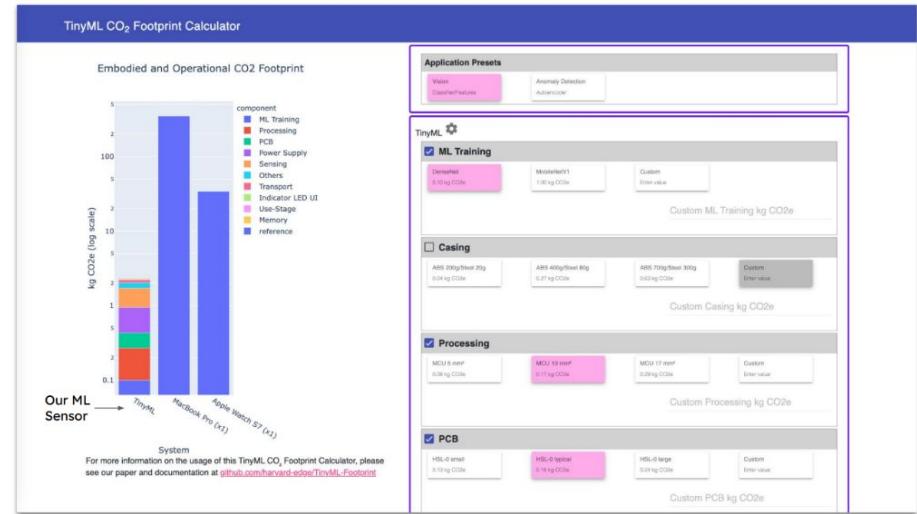
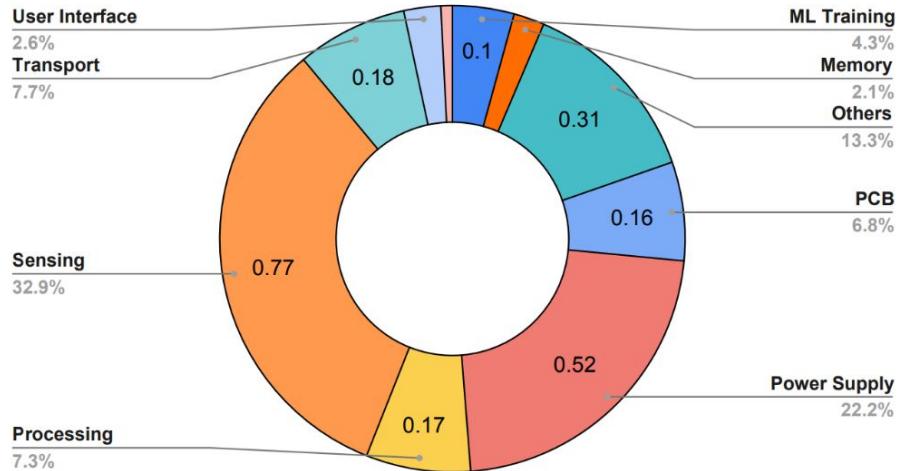
1. Raise the level of **abstraction**
2. Transparent at the hardware, data, model, and **end-to-end layers**
3. Support **Responsible** Use

Overall System
Analysis



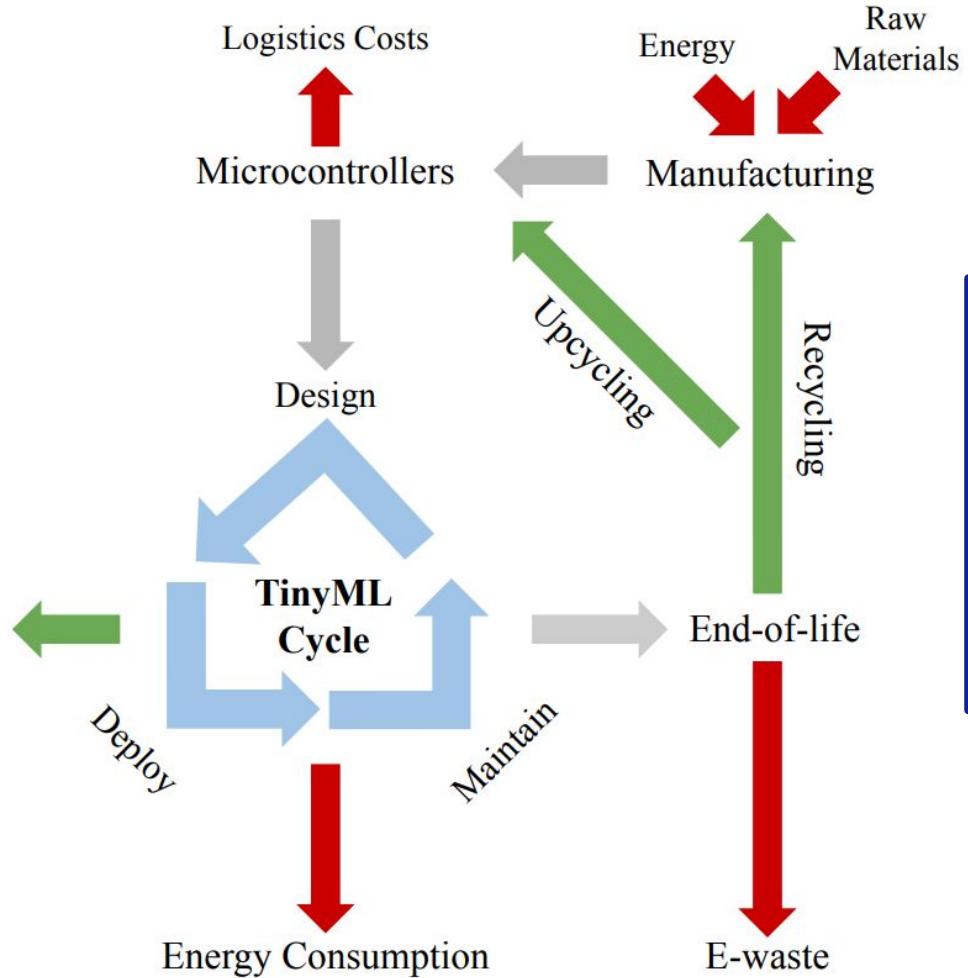
End-to-End Responsible Performance Analysis

Environmental Impact



Lets Explore this Impact
in More Detail

Sustainable Development Goals



TinyML can support the SDGs but comes with costs. **What is the net impact?**

Applications of TinyML for Sustainability

Zero Hunger & Good Health and Well-Being (SDG #2 & #3)



Credit: PlantVillage Nuru

Nuru, an ML app more accurate than humans at detecting plant diseases. Increased a farmer's sales by 55% & **yields by 146%**.



Credit: Crop Angel Ltd

Tiny drones can provide targeted pesticide applications that **reduce use to 0.1%** of conventional blanket spraying.



Credit: Sinhyu/Getty Images

Using Edge Impulse, a system was prototyped to identify mosquitoes by wing beats sounds with **88.3% accuracy**.

Life on Land & Below Water

(SDG #14 & #15)



Credit: Rainforest Connection

Rainforest Connection uses **recycled smartphones** for **solar-powered** listening devices to warn of **deforestation** efforts



Credit: RESOLVE and Bivash Pandav

RESOLVE's AI camera transmits notifications of elephant detection and can **run for more than 1.5 years** on a single battery.



Credit: Tim Cole

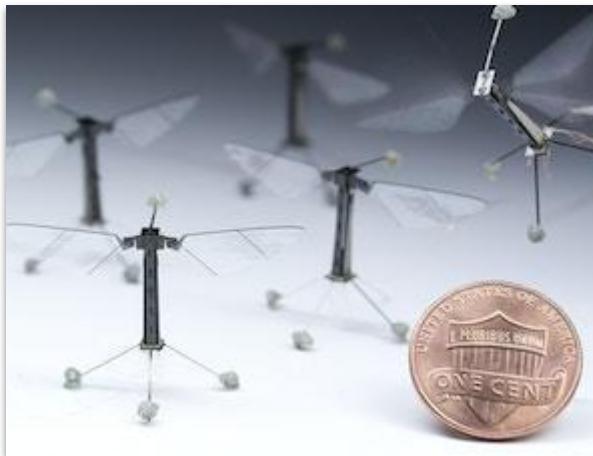
To prevent collisions with whales in busy waterways, Google deployed a TinyML model on hydrophones to alert ships.

Climate Action (SDG #13)



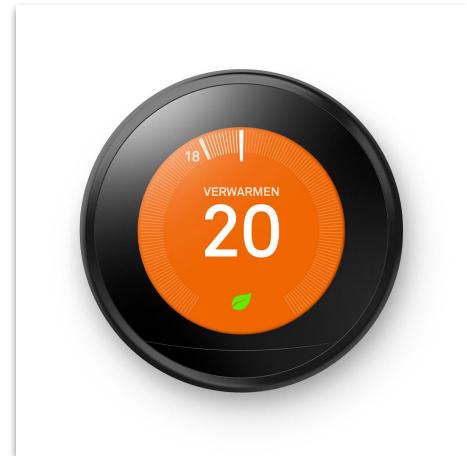
Credit: Ribbit Network

Ribbit Network is **crowdsourcing world's largest greenhouse gas emissions dataset** through distributed intelligent sensors



Credit: Wyss Institute at Harvard University

TinyML can help provide intelligence to **tiny robots like the Robobee** that can be used as artificial pollinators.

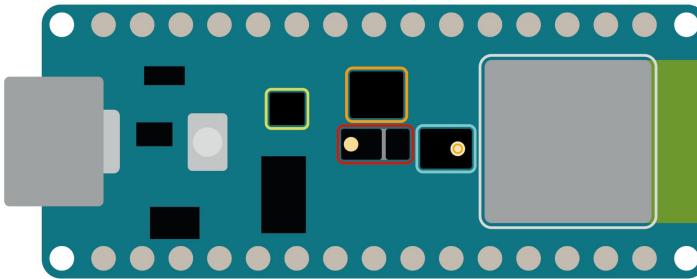


Credit: Google Nest

Smart HVAC systems show a **20-40% reduction in building energy usage**.

Environmental Footprint of TinyML Systems

Real TinyML Systems are more than just an MCU!

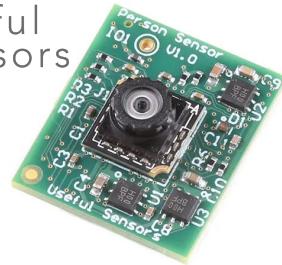


- ◆ Color, brightness, proximity and gesture sensor
- ◆ Digital microphone
- ◆ Motion, vibration and orientation sensor
- ◆ Temperature, humidity and pressure sensor
- ◆ Arm Cortex-M4 microcontroller and BLE module

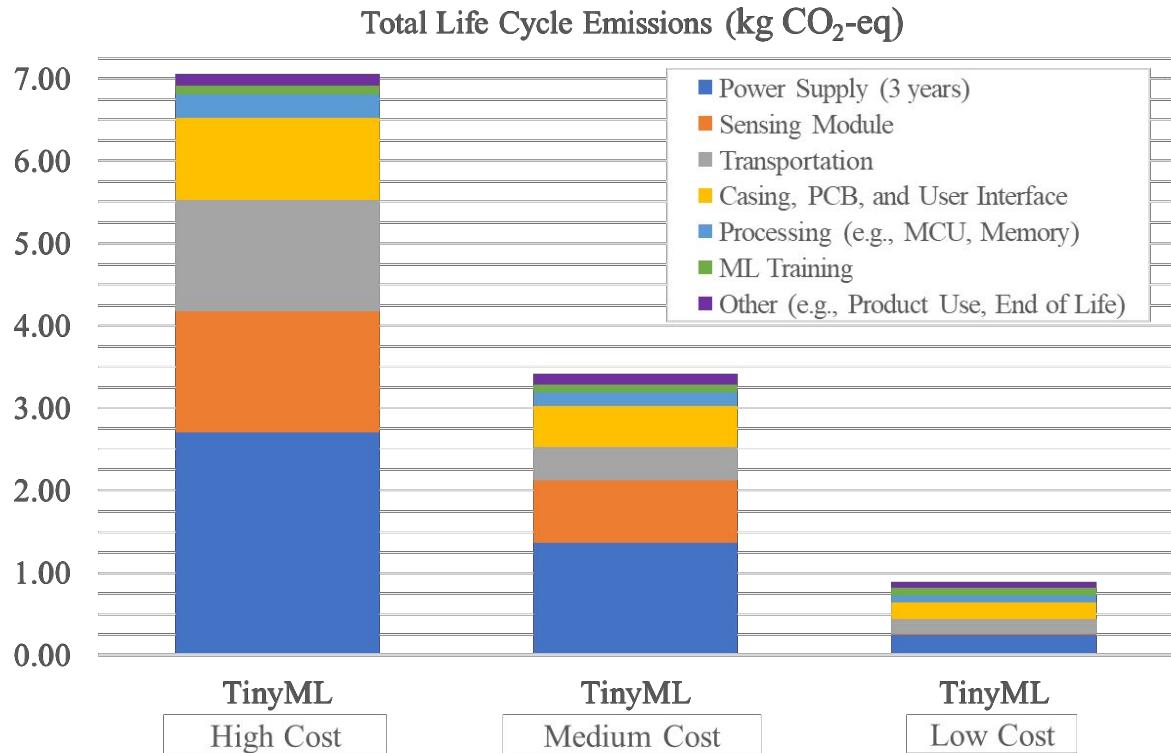


Building Representative Systems

Cost Level	High Cost	Medium Cost	Low Cost
Application	Image Classification		Keyword Spotting
Size	Large	Compact	Compact



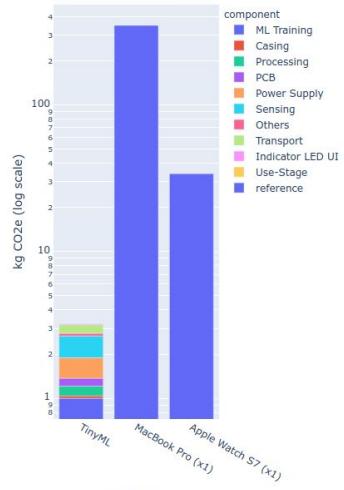
Building Representative Systems



harvard-edge.github.io/TinyML-Footprint/

TinyML CO₂ Footprint Calculator

Embodied and Operational CO₂ Footprint



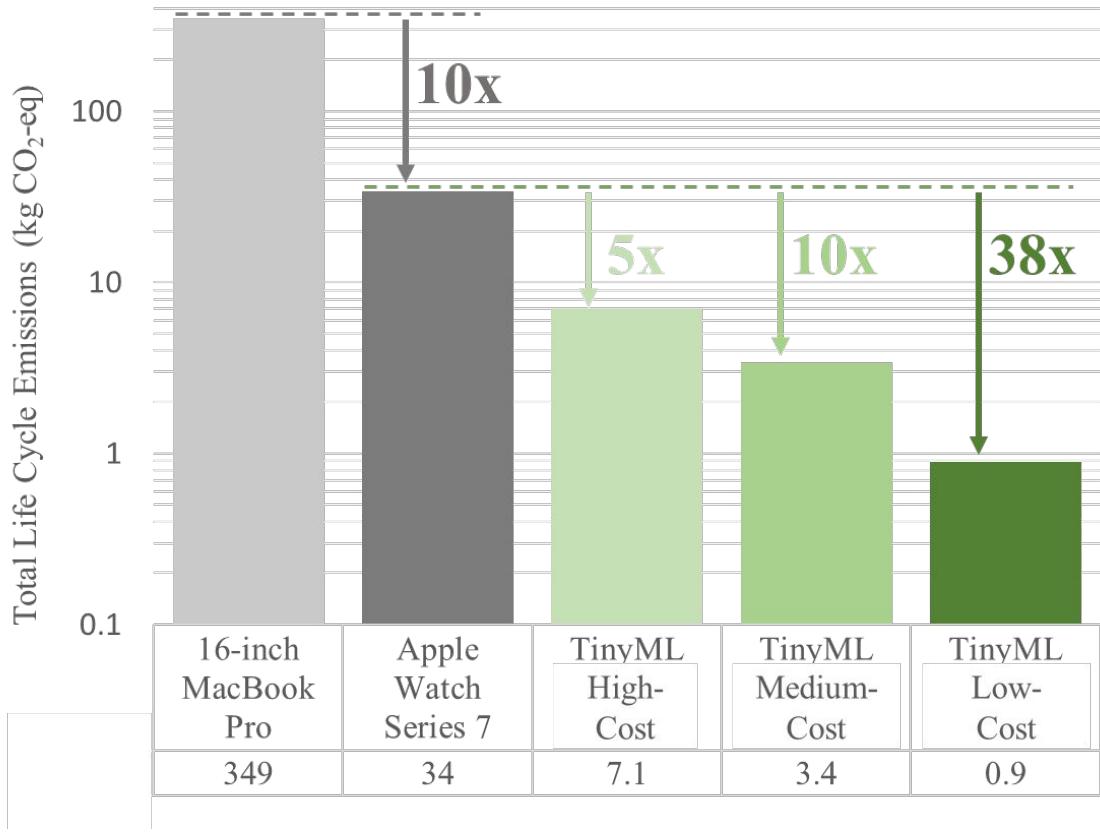
For more information on the usage of this TinyML CO₂ Footprint Calculator, please see our paper and documentation at github.com/harvard-edge/TinyML_Footprint

The screenshot shows the TinyML CO₂ Footprint Calculator interface. At the top, there is a section titled "Application Presets" with options for "Vision" (Classifier/Features) and "Anomaly Detection" (Autoencoder). Below this is a main area divided into several sections: "ML Training", "Casing", "Processing", "PCB", and "Power Supply". Each section contains a list of components with their CO₂ emissions values, some of which are highlighted in pink. There are also "Custom" input fields for each section.

Section	Component	Value
ML Training	DenseNet	0.10 kg CO ₂ e
	MobileNetV1	1.00 kg CO ₂ e
Casing	ABS 200g/Steel 20g	0.04 kg CO ₂ e
	ABS 400g/Steel 80g	0.27 kg CO ₂ e
	ABS 700g/Steel 300g	0.63 kg CO ₂ e
	Custom	Enter value
Processing	MCU 5 mm*	0.08 kg CO ₂ e
	MCU 10 mm*	0.17 kg CO ₂ e
	MCU 17 mm*	0.29 kg CO ₂ e
	Custom	Enter value
PCB	HSL-0 small	0.12 kg CO ₂ e
	HSL-0 typical	0.16 kg CO ₂ e
	HSL-0 large	0.24 kg CO ₂ e
	Custom	Enter value
Power Supply	Custom	Enter value



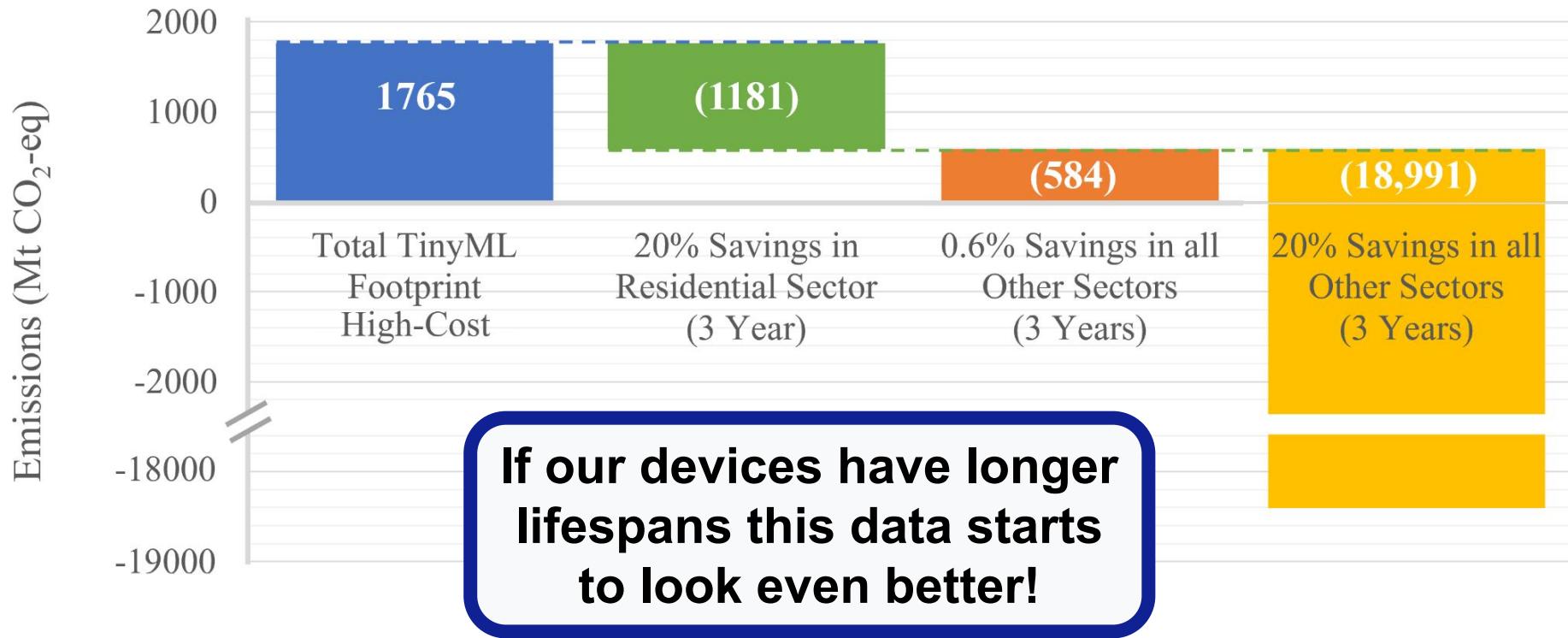
TinyML Systems in Context



**5x to 38x
Savings
over a
3-year
lifespan!**

Environmental Footprint of TinyML Systems at Deployed Scale

What if we scale to 250bn devices?



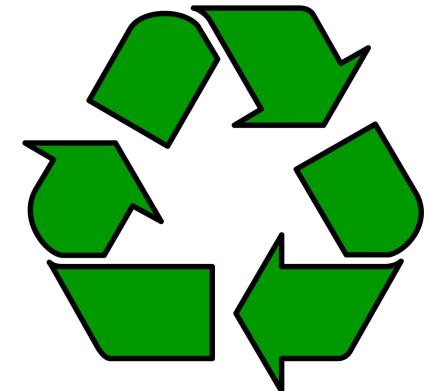
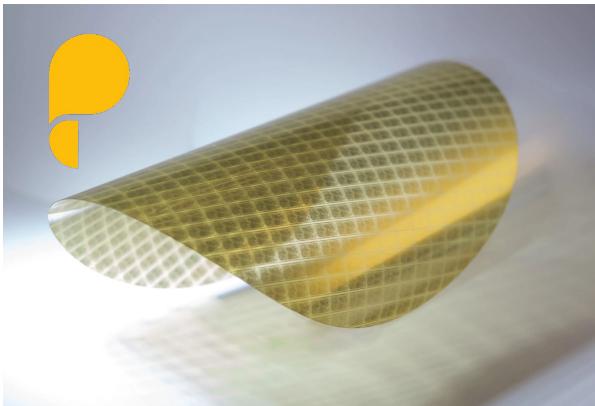
Limitations and Areas for Future Study

What about the net impact
of factors **beyond carbon**?

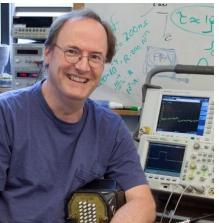
What about
Jevons' Paradox?

What about the
human costs?

How can **emerging**
technologies help?



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