NREL Transforming ENERGY

A New Understanding of Decarbonizing Industrial Process Heat

Colin A. McMillan

Sr. Analyst, NREL Strategic Energy Analysis Center, Industrial Systems & Fuels

Affiliated Research Faculty, Virginia Tech Department of Science, Technology and Society

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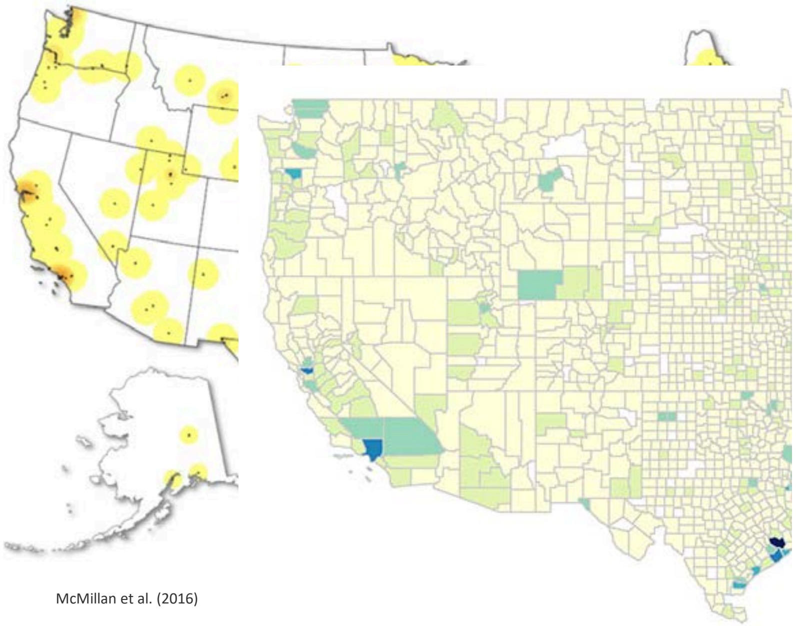
“The freedom to reshape technology and society depends on the depth of understanding.”

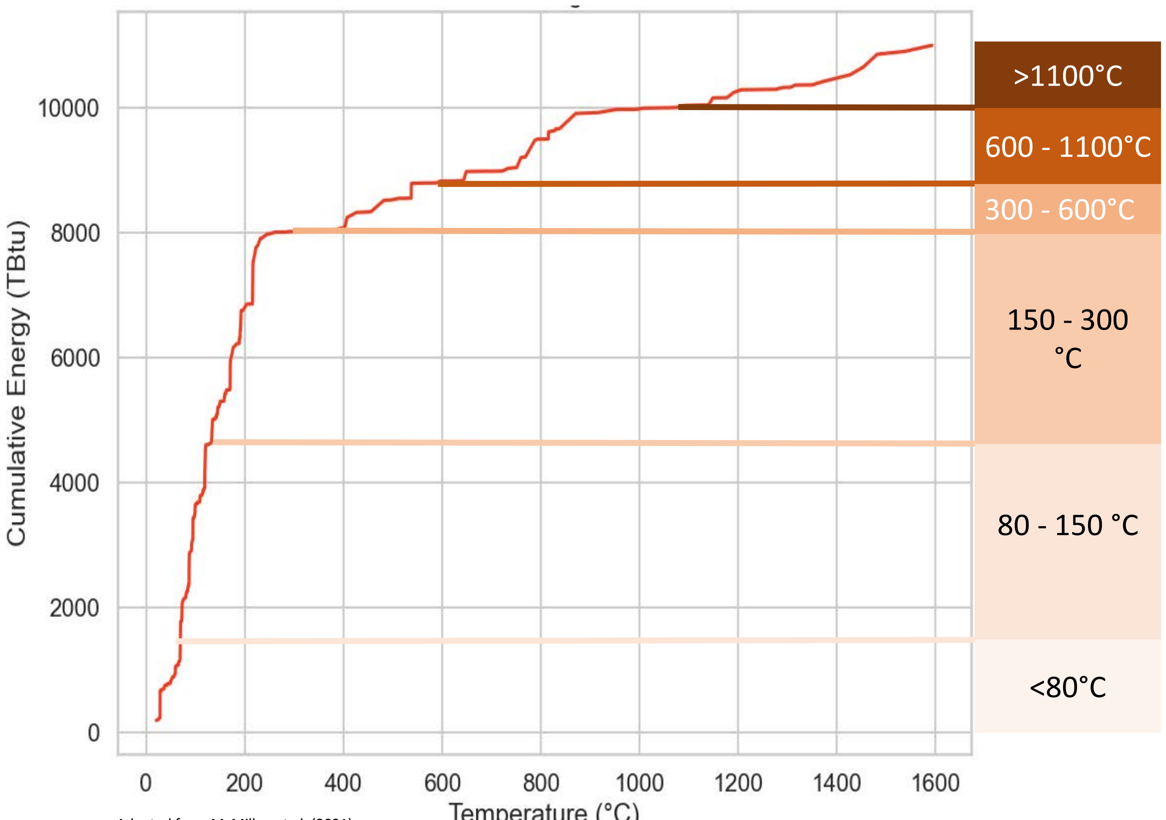
Freeman (1991, p. 228)

A Deeper Understanding for Industrial Decarbonization



McMillan et al. (2016)

McMillan et al. (2021)



Adapted from McMillan et al. (2021)

Hard-to-abate (?)

Not-so-hard-to-abate (?)

Easy-to-abate (?)

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A Deeper Understanding for Industrial Decarbonization

How and why do U.S. firms adopt and implement industrial process heat (IPH) decarbonization technologies?

What are the technical and non-technical user requirements of IPH adoption and implementation and what do they imply for decarbonization technologies?

What Do Industrial Users Have to Say about Adoption and Implementation?

- How would you evaluate an alternative source of heat for your production process?

What user requirements & associated metrics?

Which individuals and groups involved?

- In the past have there been any significant changes made to your heating processes (equipment replacement, retrofits)?

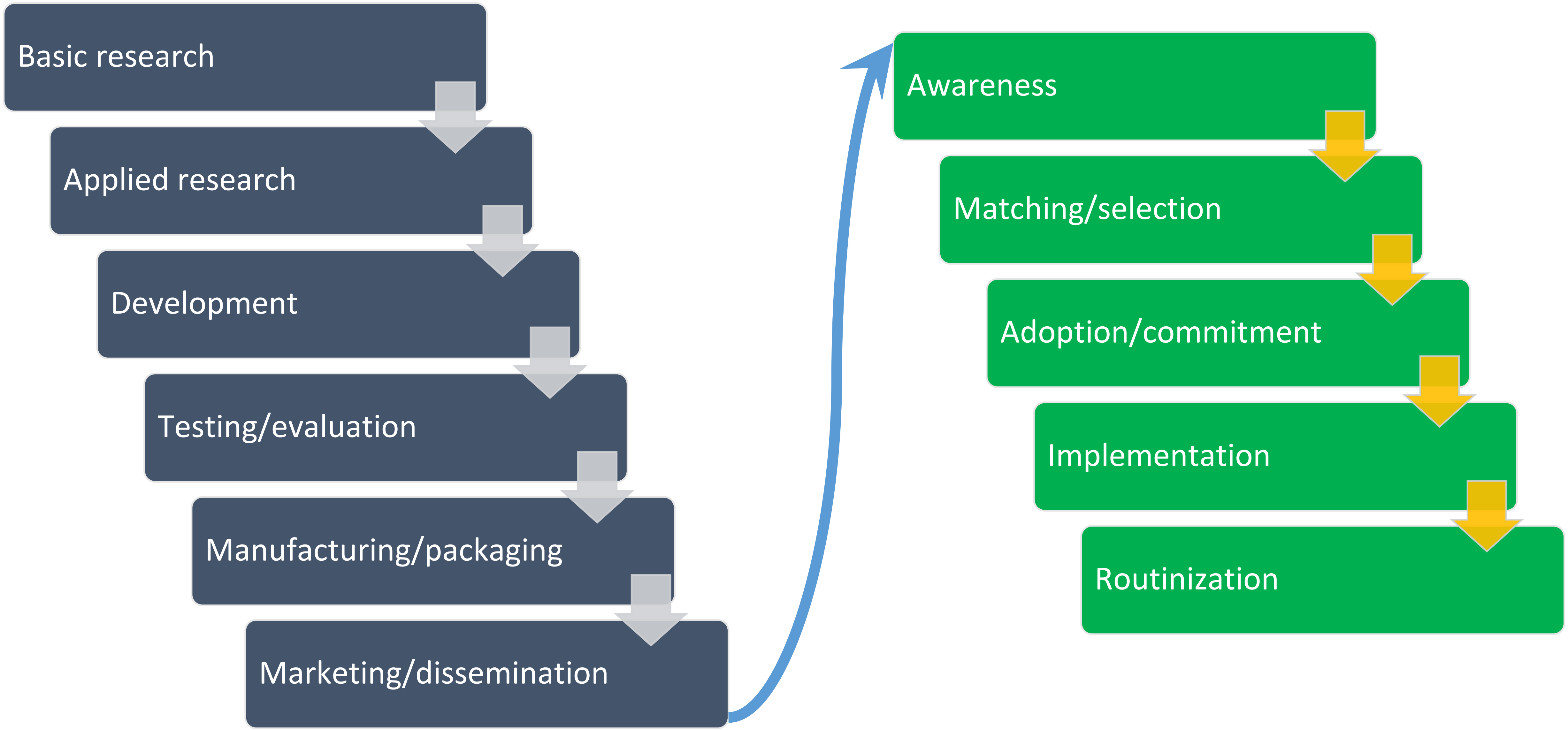
What user requirements & associated metrics?

Which individuals and groups involved?

What problems & solutions?

Technology Producer-Centric Model

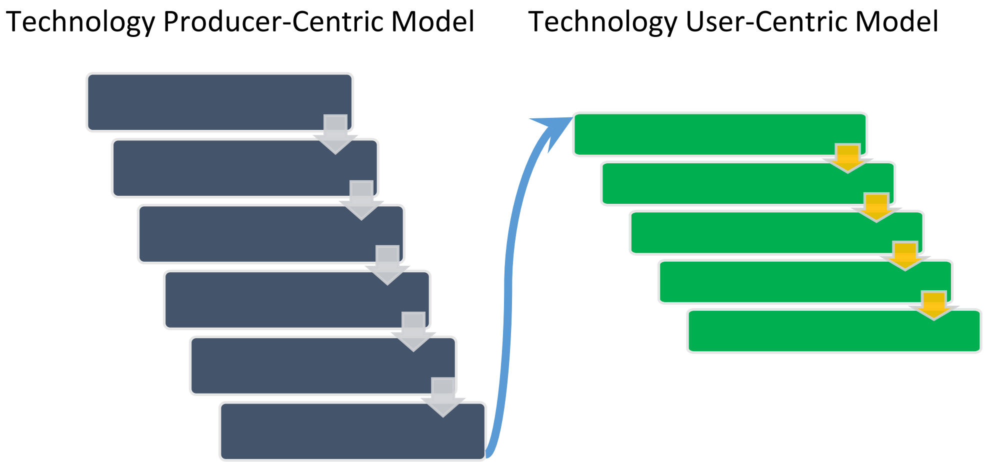
Technology User-Centric Model



Adapted from Tornatzky et al. (1983)

Generic vs. Configurational Technology Systems (Fleck 1993)

- Identity
- Systematicity
- System dynamics



A Generic Technology System

Generic Technology Systems (Fleck 1993)

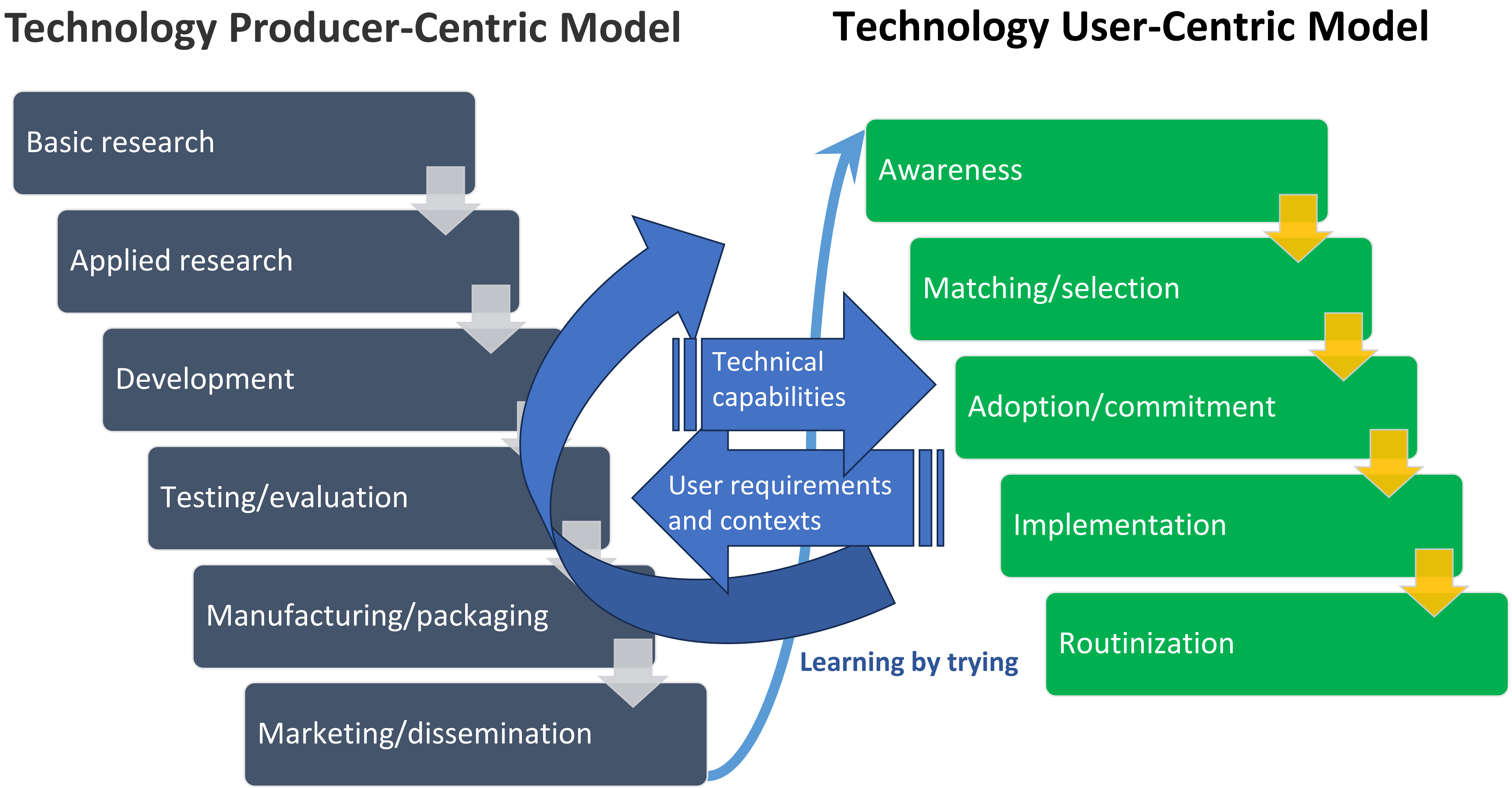
- **Identity**
  - An established identity across instances
  - Standards for function and performance
  - Existing markets for system and its standard components

Generic Technology Systems (Fleck 1993)

- Identity
- **Systematicity**
  - An underlying coherence that defines how components relate and how they're integrated.
  - The existence of standard plans for building systems and the provision of standard parts to realize those plans.

Generic Technology System (Fleck 1993)

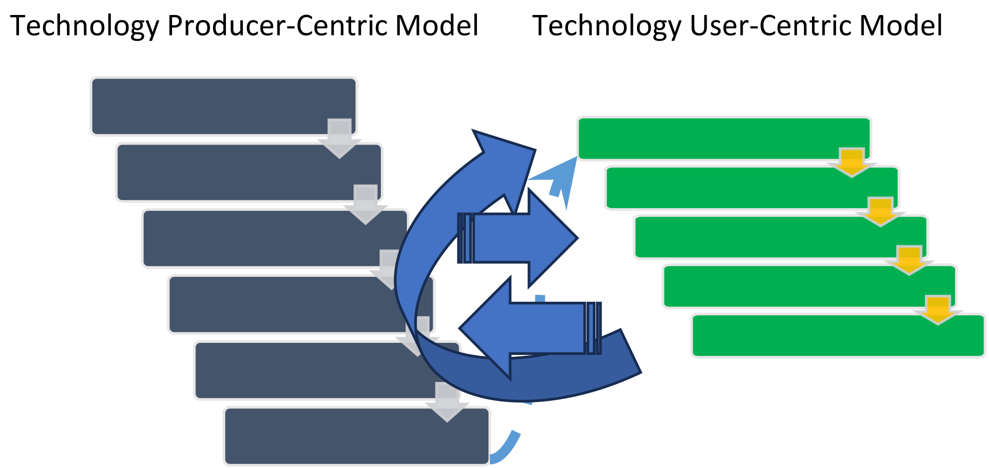
- Identity
- Systematicity
- **System dynamics**
  - An inherent logic that firmly structures development over time.
  - Because of the generic identity and systematicity, innovations happen in a well-defined space.
  - Technology suppliers can innovate independently of application contexts.



Adapted from Tornatzky et al. (1983)

Configurational Technology System (Fleck 1993)

- Identity
  - Ad-hoc
- Systematicity
  - "Shape" defined by particular application and its contingencies
- System dynamics
  - Uncertain technology development trajectory ("innofusion")



A Configurational Technology System

- Identity
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IPH as a Configurational Technology System

IPH as a Configurational Technology System: Identity

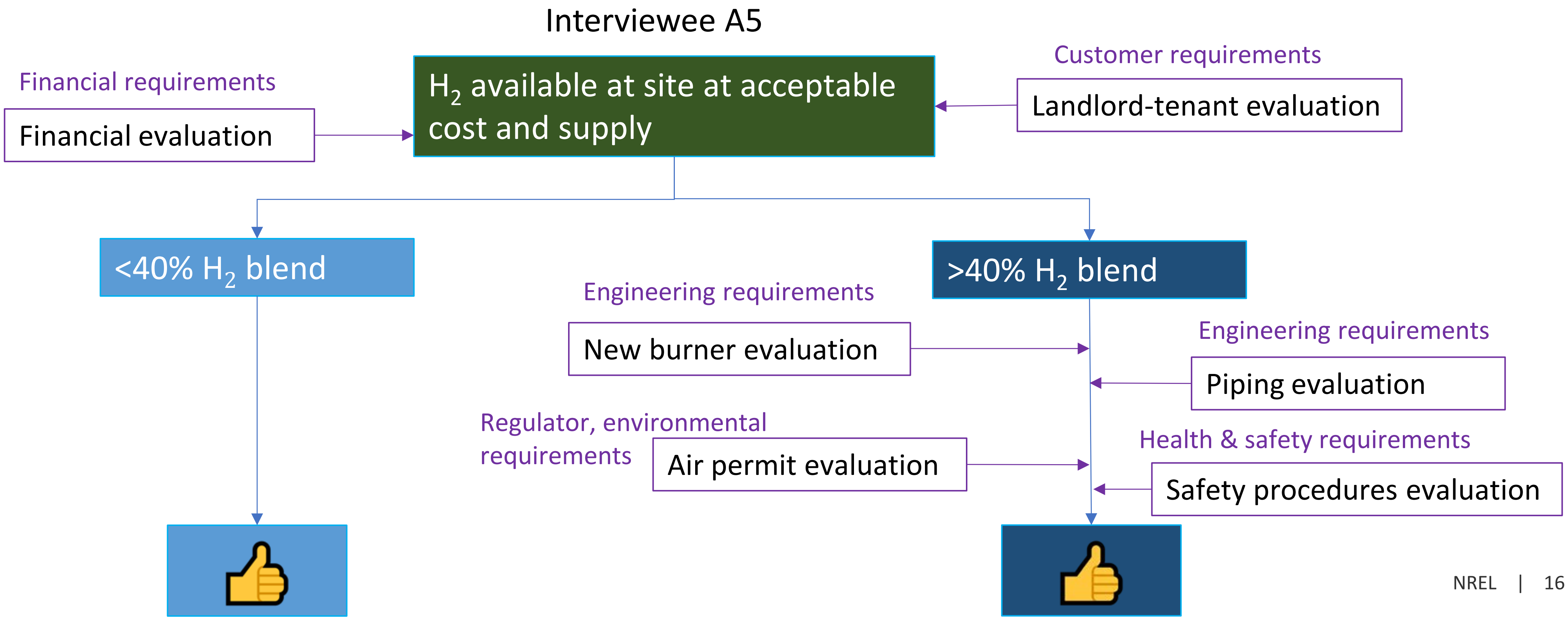
- **Identity**
  - Ad-hoc

"I mean, every plant is different because it makes different products. It has different configurations, and it might have different technologies. You might have different ages and so you have to look at it a plant at a time in order to determine what's the best transformation or change that you need to make.". (Interviewee A12).

"… the company as a whole has embraced the understanding that, like, we're moving away from traditional fossil fuel generated heat…it's a very local and a very site-specific answer to that question based on local resources and local things…"(Interviewee A8).

IPH as a Configurational Technology System: Systematicity

- **Systematicity**
  - "Shape" defined by an application and its contingencies



IPH as a Configurational Technology System: System Dynamics

- **System dynamics**
  - Uncertain technology development trajectory

"Can't you, [the DOE's national laboratories], just give us the answer? Guys like me, do each of us need to discover this for ourselves? Can't you just put out a paper that says, 'hey, if you've got a natural gas boiler that's giving you, like, this temperature steam, the best way to decarbonize is by following these five steps'..." (Interviewee A6)

"I know to electrify our plants, it was, you know—our engineers took almost two years of, 'okay, is this gonna work for us?' … In the first electrification project, you know, it's not just straight electric. They actually install[ed] the capability of both electrical heating and natural gas heating as a backup, but the subsequent electrification project they realized, 'OK, we're confident with the electric heating elements. We no longer need the backup.'" (Interviewee A7)

IPH as a Configurational Technology System: System Dynamics

- **System dynamics**
  - Uncertain technology development trajectory

“I'll say there's a bias to looking for partnerships and sort of buying decarbonized energy in the future as opposed to buying the equipment that does it ourselves.” (Interviewee A9b)

Implications for Shifting from Generic to Configurational Framing

- User technical and nontechnical requirements and user contexts are essential for successful adoption and implementation
- Learning processes and innovation occur during implementation and diffusion
- Questions framing of IPH technologies as "cross-cutting"
- Opportunities to accelerate adoption and implementation by
  - Linking users and technology developers
  - Creating identity and systematicity by developing and **transferring** standardized knowledge of full range of user requirements and contingencies

A Policy Test for IPH Configurations: South Coast AQMD

- Proposed Amended Rule 1153.1: Emissions of Oxides of Nitrogen from Commercial Food Ovens
- Multi-phased: proposed zero NOx and CO by 2027-2030

"'Commercial bakeries do not all use the same ovens or vendors, and a "one size fits all" approach is not possible,' Rasma Zvaners, vice president of regulatory and technical services at the American Bakers Association, said by email. For oven-makers, a key challenge is delivering equipment that can produce the same taste, texture and appearance as their gas- or oil-burning counterparts." (Gallucci, 2023)

Thank you

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