New title: Understanding implementation barriers in energy and climate policy: Applying and advancing frameworks from implementation science

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While theory-based evaluation in climate and energy policy is widely established, many evaluations fail to adequately capture the contextual complexity of implementation. Program evaluations often focus narrowly on internal program logic, which may suffice to understand performance but not broader impact. In energy efficiency programs, for instance, evaluations may track disbursement of subsidies or uptake of retrofitting measures, while omitting the systemic and behavioral factors that inhibit broader market transformation – such as information asymmetries among homeowners or financing constraints among technology providers (Sandin et al. 2019).

Here we aim to respond to the persistent implementation gap in energy and climate policy by proposing a structured approach to assessing barriers through the lens of implementation science. Originating in public health, implementation science offers theory-informed frameworks for diagnosing challenges that arise from the interaction between policy content, implementation actors, and context. Their focus lies on the assessment of implementation strategies rather than the effectiveness of an intervention itself. While these frameworks have gained traction in health and education, their application to climate and energy policy remains limited. The aim of this study is to bridge this gap by conducting a systematic overview of existing implementation science frameworks and discuss their applicability to climate and energy policy evaluation.

The review identifies and classifies implementation frameworks into three analytical categories. First**, process-based frameworks** conceptualize implementation as a sequence of interrelated stages and emphasize stage-specific barriers. For example, the Consolidated Framework for Implementation Research (CFIR) offers a structured model consisting of five domains: intervention characteristics, the outer and inner setting, characteristics of individuals involved, and the implementation process (Damschroder et al. 2022). The RE-AIM framework similarly introduces five dimensions – reach, effectiveness, adoption, implementation, and maintenance – highlighting the importance of implementation fidelity (Holtrop et al. 2021; Glasgow et al. 1999). However, due to its origins in health science it tends to assume short feedback loops, which may limit its direct applicability to climate policies. Complementing these, Moser and Ekstrom's Diagnostic Framework for Climate Change Adaptation maps the adaptation decision-making process and systematically identifies barriers related to actors, context, and system dynamics in the climate action context (Moser and Ekstrom 2010). These models share a commitment to capturing the evolution of barriers across the policy cycle and highlight the need for stage-specific intervention strategies. However, they often fall short in systematically identifying relevant stakeholders and delineating their roles.

The second category of frameworks emphasizes **actor-centric analysis**, focusing on the differentiated roles and perspectives of actors and stakeholders in the implementation process. These include also models that analyze related factors such as authority and capacity, and frameworks like the Theoretical Domains Framework (TDF) that examine factors (barriers and facilitators) that influence a given behavior (Atkins et al. 2017). Such frameworks highlight not only actor characteristics but also the relationships among them and the context in which they are embedded. This approach is particularly relevant in climate and energy governance, where policy outcomes depend on a broad network of actors – ranging from regulatory authorities and private financiers to end-users and service providers – whose incentives and capabilities vary significantly.

The third category of frameworks centers on the **typological assessment of barriers**. For example, Lee et al. (2022) provide a categorization of barriers to national adaptation policy, such as lack of resources, fragmentation, or limited communication. These frameworks are valuable for offering structured entry points for analysis but often remain disconnected from dynamic implementation processes or actor-specific insights.

Building on practical experience applying the **Theory of No Change (TONC)** framework in projects on developing, conceptualizing, and evaluation climate action plans for different German states, we argue that the TONC developed by Arepo (Wörlen et al. 2016) provides for a particularly relevant and actionable framework to assess implementation of climate policies by synthesizing a stakeholder-centric analysis with a typological assessment of barriers. Specifically designed for analyzing energy and climate policies, TONC moves beyond traditional theories of change by focusing on why intended transformations fail to materialize. It identifies barriers by assessing **four key stakeholder groups** – users, providers, financiers, and policymakers – across **six generic types of barriers**: lack of awareness, lack of knowledge, lack of affordability, lack of motivation, lack of cost-effectiveness, and lack of access. Developed through meta-analyses of energy efficiency evaluations, **TONC offers a pragmatic tool to diagnose failures in policy implementation**. Its structured stakeholder-barrier matrix provides a clear and communicable diagnostic, allowing practitioners to visualize critical issues – such as users lacking awareness, financiers lacking incentives to participate, or a combination of both – and trace these directly to policy design flaws.

TONC's strength lies in its **sectoral relevance and systemic perspective**. It accounts for the full chain of actors required for successful implementation and highlights that failure may stem from any link in this chain. However, TONC also has its limitations. It is less process-oriented than frameworks like the CFIR, and while it identifies the "what" of barriers – and, thus, the reason why an intervention may fail – it does not systematically elucidate reasons "why" barriers exist. Barriers such as "lack of motivation" may result from diverse psychological, institutional, or contextual drivers – areas that can be more deeply explored through complementary frameworks such as the TDF. Additionally, the four stakeholder categories used in TONC may not capture the full diversity of actors in more complex policy contexts and may require adaptation.

Accordingly, our comparative analysis reveals that **implementation science frameworks are not mutually exclusive**. Moreover, they offer complementary insights which can be used at different phases of the policy cycle. During the policy design phase, frameworks like TONC can help anticipate barriers and support more robust program planning. For example, a pre-implementation TONC analysis might flag the need for user awareness campaigns or training for providers. CFIR can concurrently be used to assess contextual readiness by examining political support, institutional capacity, or stakeholder alignment. During implementation, frameworks such as RE-AIM provide tools to monitor reach, uptake, fidelity, and sustainability. TONC can be iteratively applied at this stage to reassess evolving barriers – such as a financier group initially considered supportive later becoming disengaged. Finally, in post-implementation evaluations, TONC can systematically identify the barriers that ultimately undermined a program's impact, while frameworks like CFIR and TDF offer depth in understanding how those barriers manifested and interacted.

In conclusion, leveraging frameworks from implementation science can significantly enhance the diagnosis and mitigation of barriers to energy and climate policy implementation. In our experience, the Theory of No Change (TONC) stands out for its pragmatic focus and sector-specific orientation. Still, its utility can be further enhanced when combined with process- and actor-oriented frameworks thereby exploring its adaptability to complex stakeholder landscapes.

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