

A Case for a Synthesized Framework for Developing Resilience Indicators and Metrics for Electrical Systems in Developing Countries

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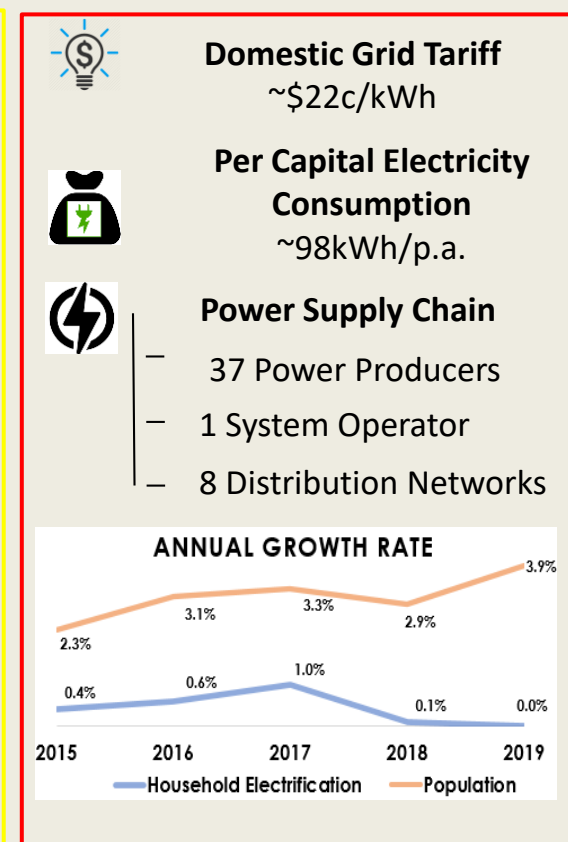
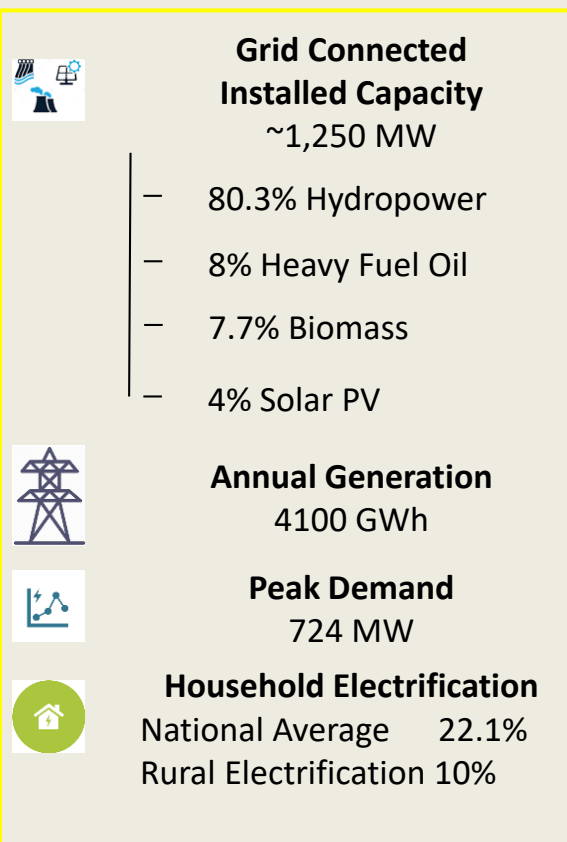
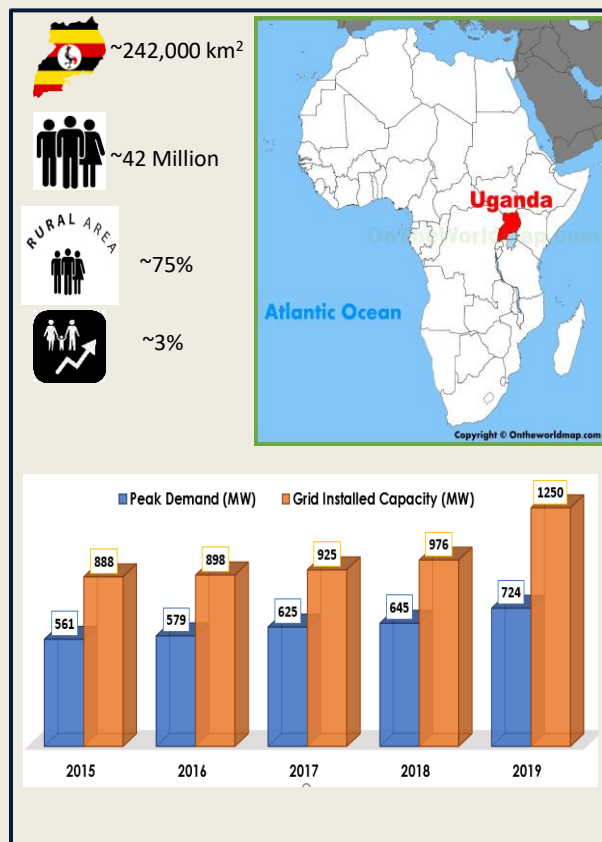
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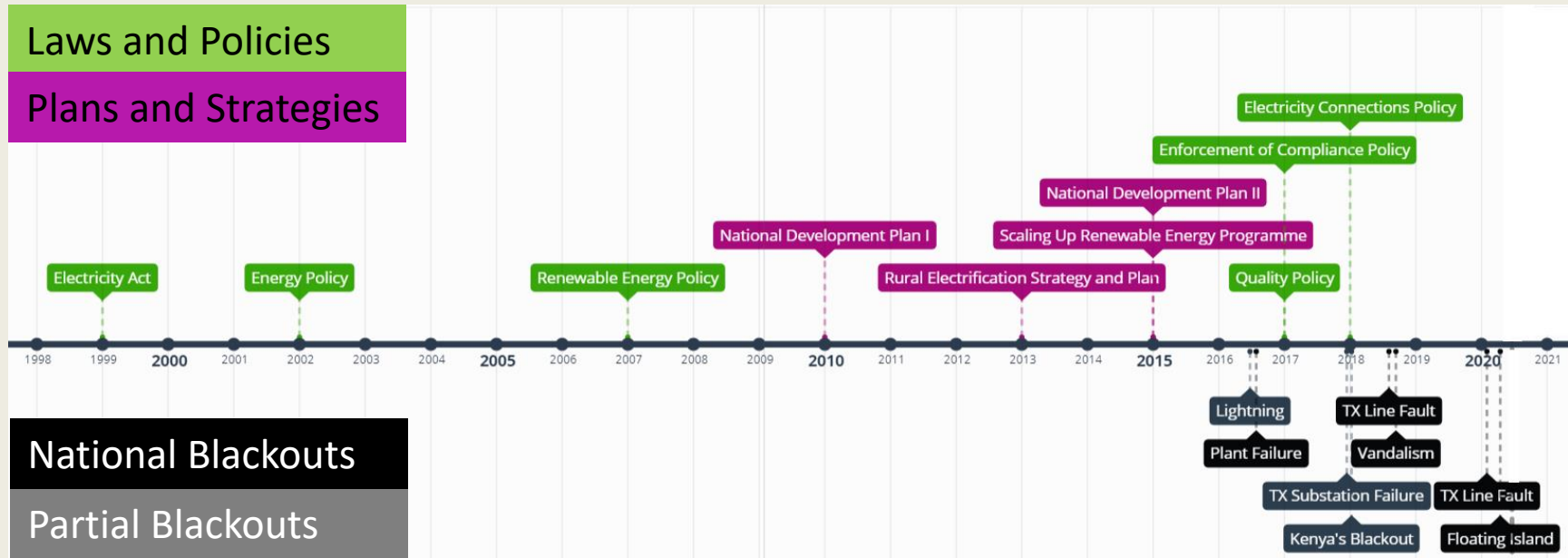
An Overview of a Developing Country

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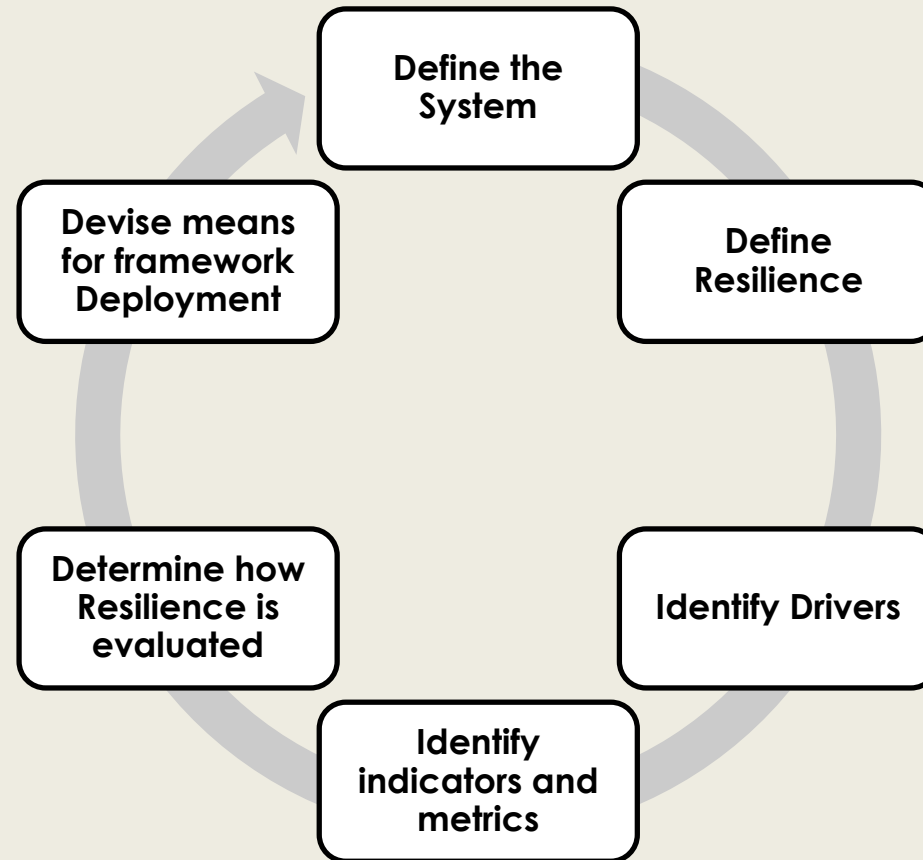
Overview Cont'd

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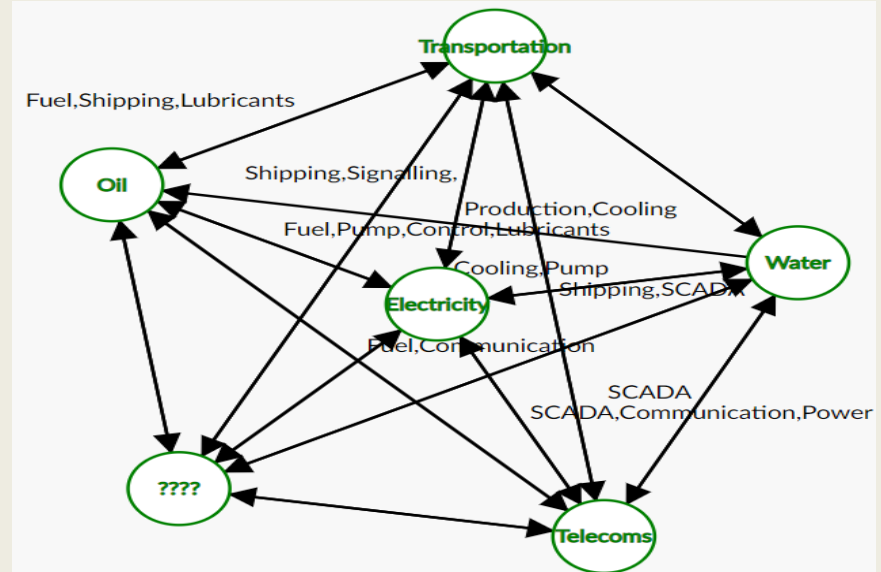
- Increase in electricity access is the key driver of sector policies and programs
- But access remains low and barely transcends beyond 'lights & radio'.
- Increased of countrywide blackouts, 8, in the last 4 years
- **Resilience thinking** has been proposed as a potential solution

Developing Resilience Frameworks



System Definition

- Electrical networks has overlapped and interconnected systems
- Stakeholders define goals which define valued development states.
- These goals can be generally captured within what we will term as “**Dimensions**”, namely; economy, wellbeing, infrastructure, Environment and Leadership



Some of the Key Stakeholders

Discipline Level: Energy, Environment, Economy, Disaster Management, Health & Wellbeing experts

National/System Level: Utilities, Policymakers, Regulators, Academia, Financiers, consumer unions

Community Level: off-grid developers, energy cooperatives

Consumer Level: household consumers, SMEs, industry, essential service providers

What does Resilience Mean?

- Definitions can be broadly categorized in **structural** (what is it?) and **operational** (what does it do?).

In general terms, Resilience is objectively described as a **measure of a disturbance** or subjectively as a **measure of response**.

Resilience is regarded as the amount of change a system can undergo whilst retaining the same control on function and structure, and the degree to which it is able to self-organize, adapt, and transform (adapted from Walker et al., (2002))

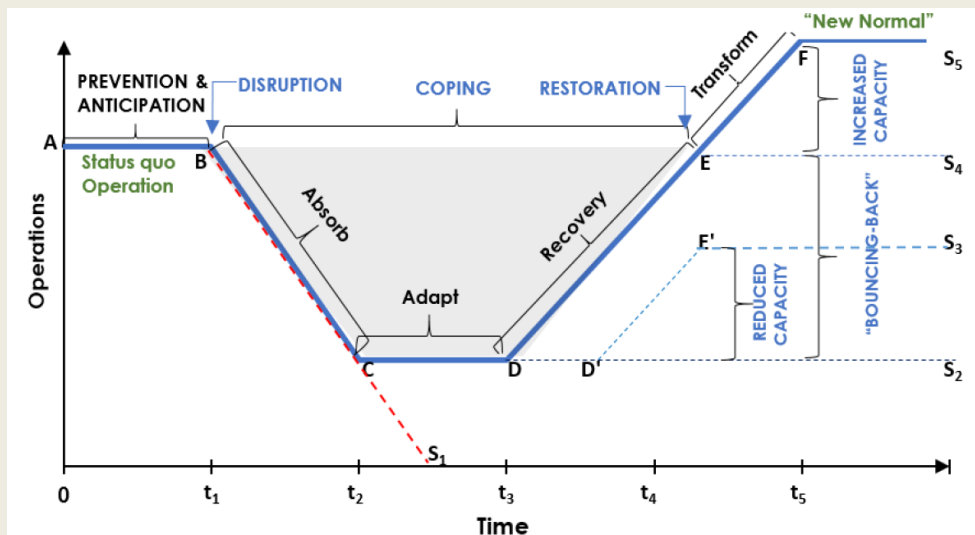
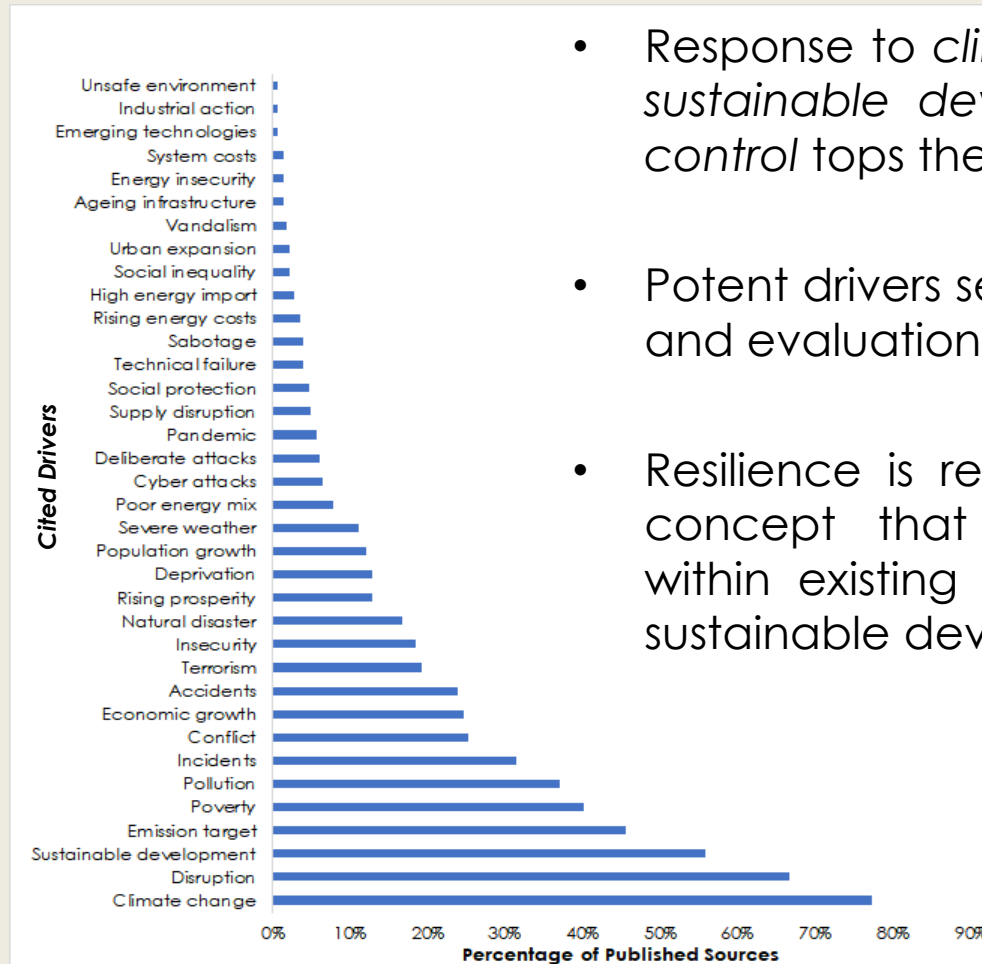


Figure adapted from Lin and Bie, 2016

Walker, B. et al. (2002) 'Resilience management in social-ecological systems: A working hypothesis for a participatory approach', *Ecology and Society*, 6(1). doi: 10.5751/es-00356-060114.

Why Resilience Thinking?

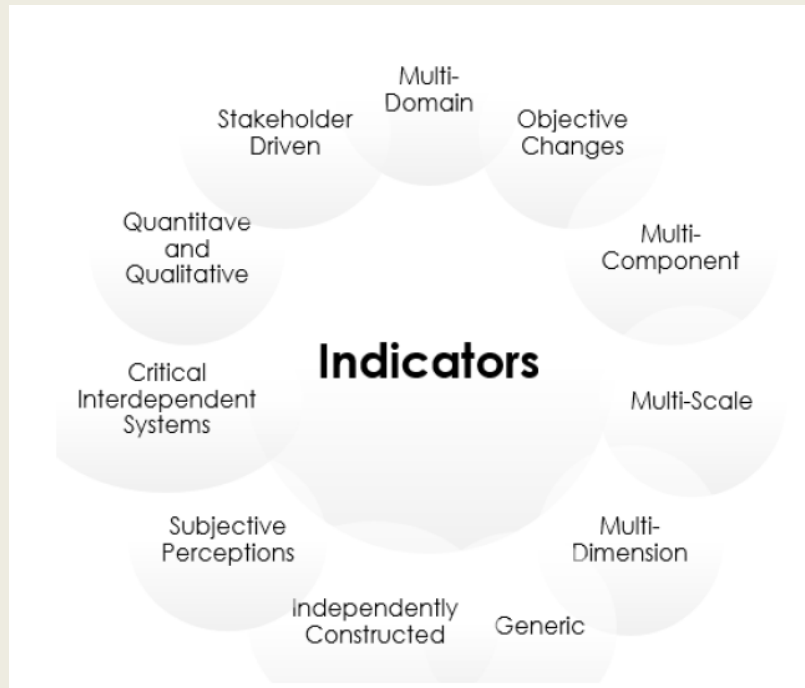
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- Response to *climate change*, disruptions, *sustainable development* and *emissions control* tops the list of drivers
- Potent drivers selected from a risk analysis and evaluation exercise
- Resilience is regarded as an organizing concept that addresses vulnerabilities within existing systems whilst advancing sustainable development.

Source of data is from 285 journal papers, collated randomly as part of the chronological study of definitions of resilience, Literature spanning 1919-2020, data extracted from 'word count' conducted within NVIVO

Characteristics of Indicators

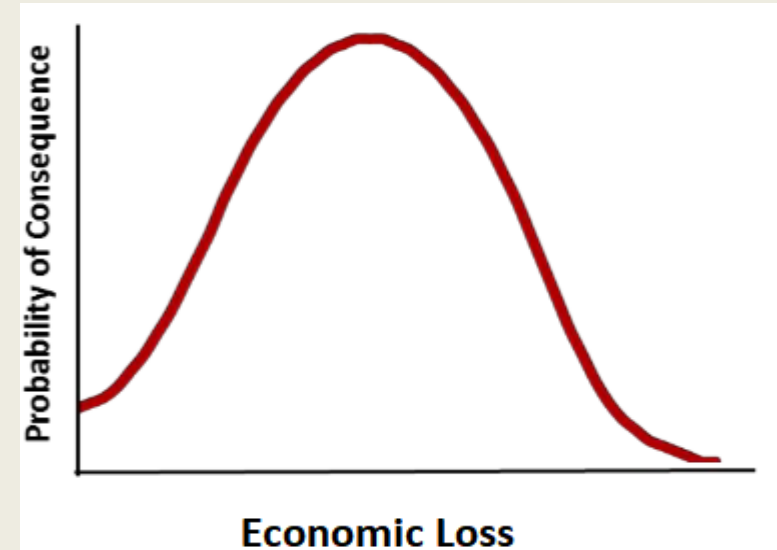


- Most frameworks elects “ecological” instead of “engineering”.
- Generally, the more diverse the indicators of the system, the more likely it is to build a more meaningful framework.
- A performance-based Indicator, such as energy not served, can be evaluated by a consequence-based metric such as economic loss.

Source of information: Béné, 2013; Roege et al., 2014; Watson et al., 2014; ARUP and TRF, 2016

So, How Is Resilience Measured?

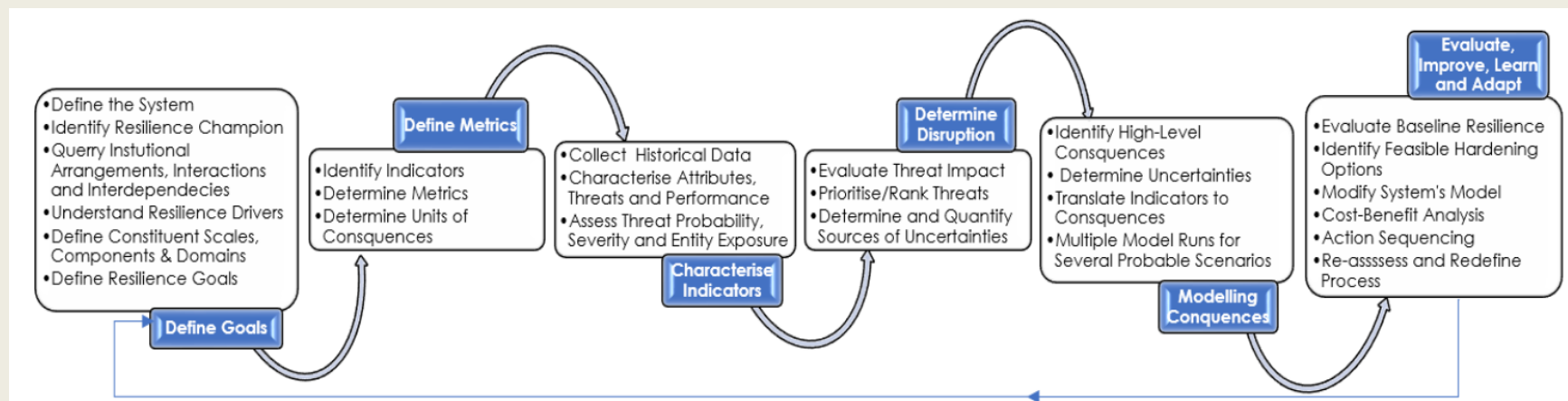
- Indicators and metrics can take the form of evaluating assets, performance, risk and consequences.
- These are identified at the intersection of **qualities/capacities** and the goals.
- Qualities are thought to be the most fundamental properties for any resilient system
- capacities are designated as “stages of change”



Recent literature prefers **probability density functions** as a measure for resilience

Deployment of Frameworks

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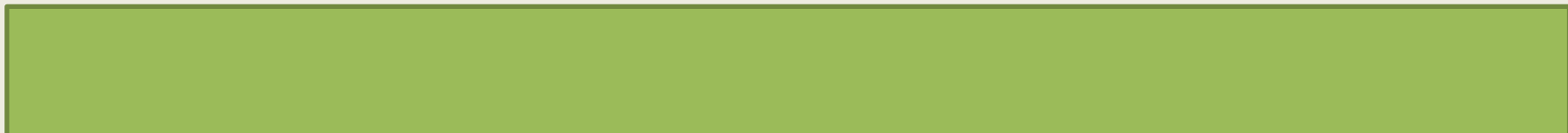
- The frameworks are executed within resilience analysis processes.
- The process should yield a baseline assessment from which appropriate action can be taken.

Figure developed with Source of Information: (Walker et al., 2002; Watson et al., 2014; ARUP et al., 2019)

So what are the Limitations with the Existing Frameworks?

| Author | Context | Framework Limitation |
|----------------------|---------------------|--|
| Béné, 2013 | Food security | The 'cost of resilience' is independent of risk and its entirely driven by the outcome |
| Roege et al., 2014 | Energy | The system and its attributes and characterized exclusively by domains. |
| Manyena et al., 2019 | Disaster Mgt. | The indicators are too generic to be used to comprehensively assess resilience for electricity systems. |
| Watson et al., 2014 | Electricity | The transformation models are mainly 'components' centric |
| Preston et al., 2016 | Electricity | Adaptation is the end goal reinforcing pre-event vulnerabilities and no linkage between responses and capacities |
| TRF et al., 2019 | Urban water systems | The model assumes that all indicators and goals, contribute to resilience equally. Goals are not linked to desired capacities. |

None of these can comprehensively deal with the **double-edged problem** in developing countries; solving the longstanding existing challenges (i.e., increasing of electricity connections) vs adherence to internationally driven development agendas (i.e., SDGs)



Resilience Vs Sustainability

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1. The 'synonymous' argument

Resilience = Sustainability

2. The 'function' argument

Sustainability = $f(\dots, \text{Resilience})$

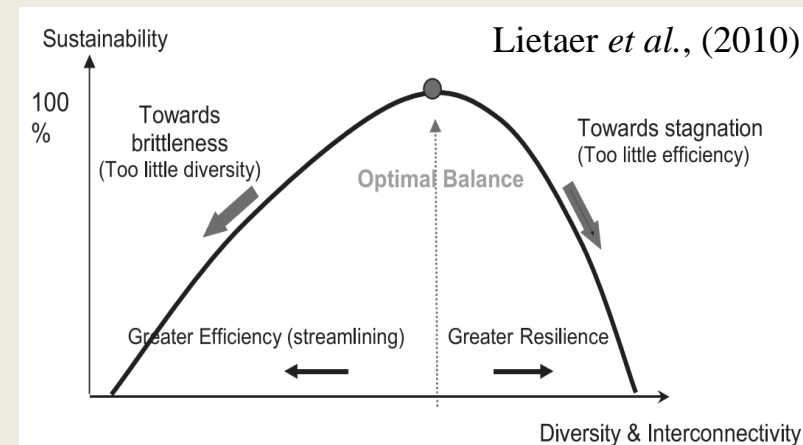
Resilience = $f(\dots, \text{Sustainability})$

3. The 'mutual exclusivity' argument

$(\text{Sustainability} \cap \text{Resilience}) = 0$

4. The 'separate but complementary' argument

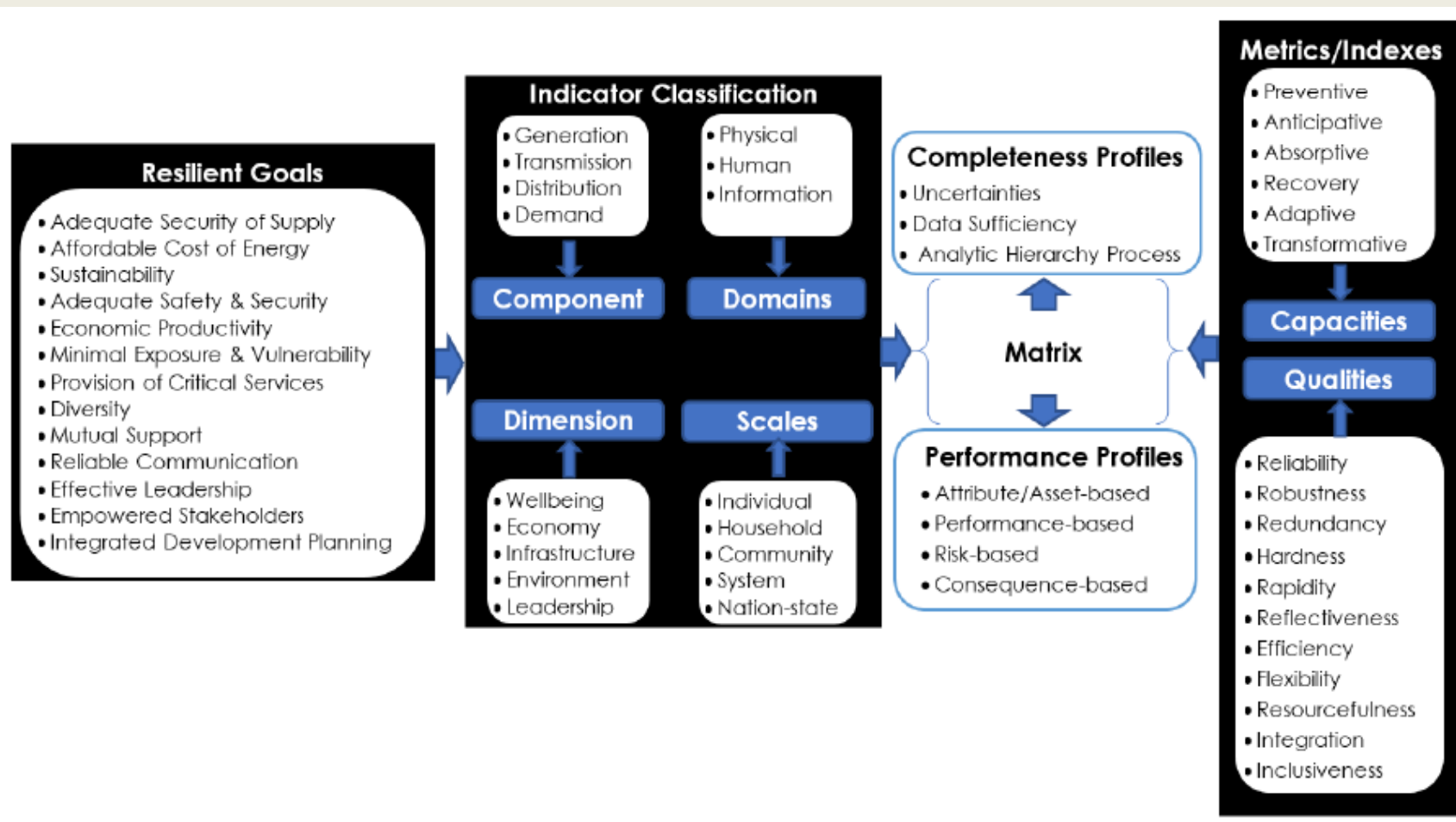
$(\text{Sustainability} \cap \text{Resilience}) \neq 0$



- Nerini *et al.*, (2017) demonstrates that 85% of the SDG targets are affected in some way by the energy goal (SDG 7)
- From Xu *et al.*, (2015), a desirable sustainable resilient system is able to maintain stocks of natural capital above existing threshold levels for socio-economic wellbeing without losing structure or control amidst disruptions
- **The two concepts are aligned on their focus on survivability and persistence of the system**

Proposed Framework

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Synthesized from Béné, 2013; Roege et al., 2014; Watson et al., 2014; ARUP and TRF, 2016; Lin and Bie, 2016; Manyena et al., 2019.

Conclusions and Future Research

- The framework systematically and comprehensively characterizes resilience indicators and metrics and therefore it enables critical interrogation of causations
- The Framework does harmonize the seemingly incongruous concepts such as resilience and sustainability.
- The proposed taxonomy of identifying indicators and metrics is meant to support holistic planning, improved operations, evidence-based policymaking and enhancement of resilience within the electricity industry.
- Next course of action will involve populating the framework. Spelling out mathematical relationships of different elements and thereafter testing it on a case study.

Thank you for Listening

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Suggestions and Questions are welcome

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