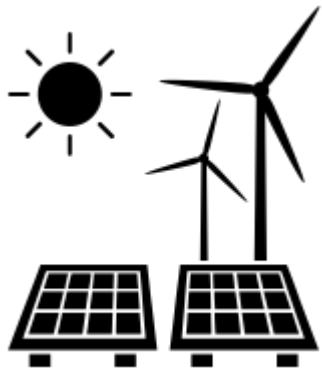# Revisiting The Growth Hypothesis
For the Renewables in the Energy-Growth Nexus
## ~Using ARDL Approach~

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Date | 2019.08.28

Contents

1. Introduction

- **Progress in renewables**
  - ✓ **International climate change issues**
  - ✓ **Sustainable development goals**

- **Concentrated in power sector**
  - ✓ **Far less growth in heating, cooling and transport in 2018**
  - ✓ **Share in power generation would rise from 25% to 86%**

[Renewable energy share in total final energy consumption (IRENA, 2019a)]
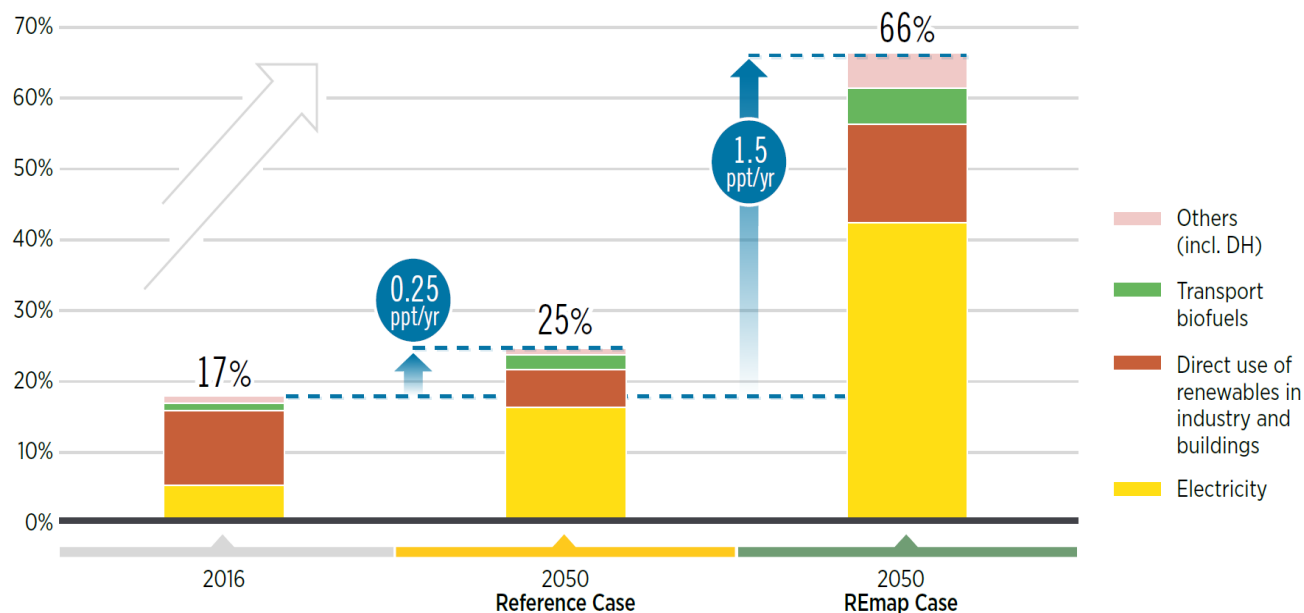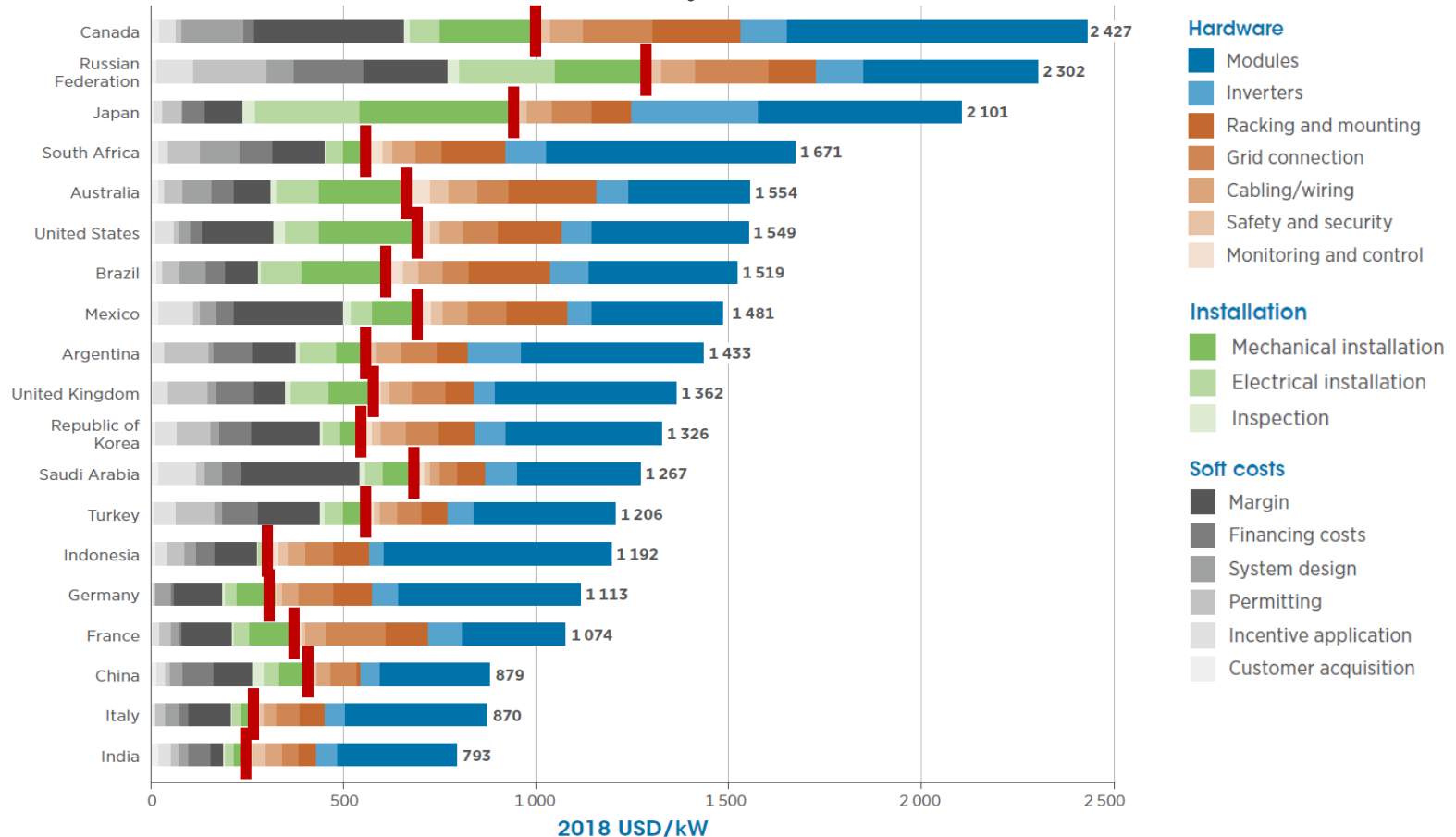
1. Introduction

- ## Different cost structure
    - ✓ **High CAPEX (capital expenditure)**
    - ✓ **Different from traditional power generation**

[Detailed breakdown of utility-scale solar PV (IRENA, 2019b)]

1. Introduction

- **About…**
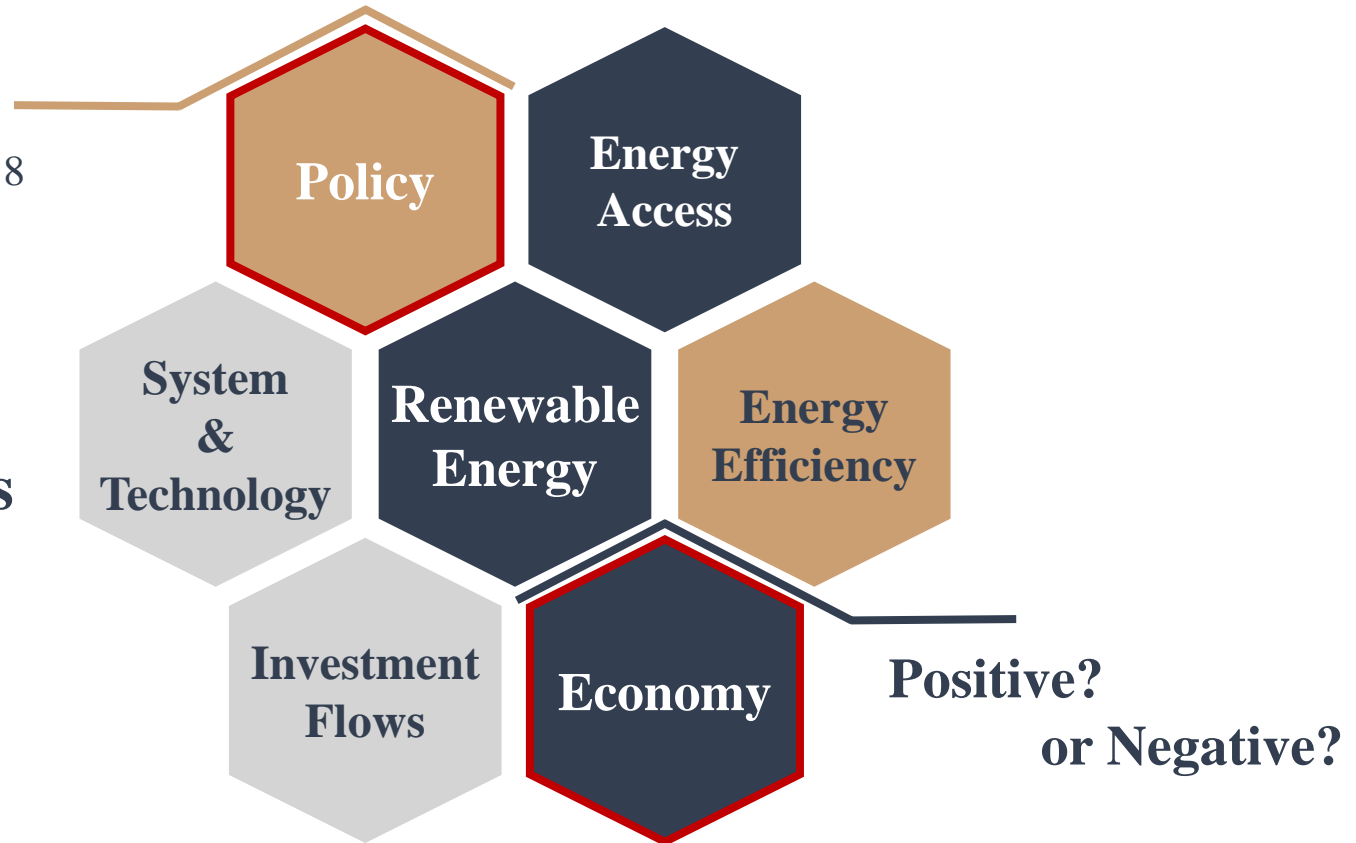
Policies

- 169 countries in 2018
- Support policies
- Target policies

Policy makers

- Reduce pollution
- Job creation
- Global trend

Policy

Energy Access

System & Technology

Renewable Energy

Energy Efficiency

Investment Flows

Economy

Positive?
      or Negative?

The economic part of renewable energy
→ Energy-Growth Nexus

2. Research Question

- ## Literature review

  - ✓ **Kraft and Kraft (1978)**
  - ✓ **Energy consumption and economic growth relationship have been investigated**
  - ✓ **It has been developed at a disaggregated level (Ozturk, 2010)**

- ## Four hypotheses (Payne, 2010)

  - ✓ **Growth**

    ; **Energy consumption plays an important role in economic growth**
  - ✓ **Conservation**

    ; **Energy conservation policies have little or no adverse effect**
  - ✓ **Neutrality**

    ; **Absence of relationship**
  - ✓ **Feedback**

    ; **Bi-directional relationship**

2. Research Question

- ## Research questions

  - ✓ **Confirmation of growth hypothesis**
    - → **Empirical analysis**
  - ✓ **Feature of renewable energy industry affect growth nexus**
    - → **Based to Thomsen-Reuter (2017)**
    - → **Countries within the PV and wind power company**

  - → **Canada, China, Denmark, Germany, India, Spain, USA**
  - ✓ **Policy implication**

3. Methodology

- ## ARDL bounds testing approach (Pesaran et al. 2001)

  ✓ **Auto-regressive Distributed Lag model**
  - → **Frequently used in recent research (cf.)**

Study	Periods	Country	Conclusion
Sari et al. (2008)	2001-2005	USA	GDP => REC
Ziramba (2009)	1980-2005	South Africa	EC ⇔ GDP
Chandran et al. (2010)	1971-2003	Malaysia	ECC => GDP
Ozturk and Acaravci (2010)	1968-2005	Turkey	$EC \neq GDP$
Alam et al. (2012)	1972-2006	Bangladesh	EC ⇔ GDP
Shahbaz and Feridun (2012)	1971-2008	Pakistan	GDP => ECC
Akinlo (2008)	1980-2003	11 Sub Sahara African countries	$GDP => EC; EC \Leftrightarrow GDP; EC \neq GDP$

  ✓ **Advantages**
  - → **Irrespective of whether underly variables are I(0) or I(1) or a combination of both (Pesaran and Pesaran, 1997)**
  - → **More significant in small samples (Pesaran and Shin, 1999)**
  - → **ARDL allows the variables may have different optimal lags**
  - → **Effectively corrects for endogeneity of explanatory variables**

3. Methodology

- # Data

  ✓ **Time series data**
  - → **From 1980 to 2016 (37 observations)**
  - → **7 countries (Thomsen-Reuter, 2017)**
  - → **Convert to natural log form**

  ✓ **Variables**

Name	Explanation	Unit	Source
GDP	Real GDP per capita	[constant 2010 US$]	WDI
NRE_EC	Non-renewable electricity consumption per capita	[watt-hours]	EIA, WDI
*RE_EC	*Renewable electricity consumption per capita	[watt-hours]	BP, WDI
K	Real gross fixed capital formation per capita	[constant 2010 US$]	WDI

*Only PV and wind

3. Methodology

- ## Econometric procedure

  - ✓ **Stationarity (unit root test)**
    - → **ADF(Augmented Dickey-Fuller, 1979)**
    - → **PP(Phillips and Perron, 1988)**
    - → **KPSS(Kwiatkowsk-Phillips-Schmidt- Shin, 1992)**

  - ✓ **Johansen and Juselius (1990)**
    - → **Confirm that there are multiple long-run relations**
    - → **Toda and Yamamoto (1995)**

  - ✓ **ARDL bounds testing approach**
    - → **Dependent variable; real GDP**
    - → **Narayan (2005); a set of critical values for small sample size (30-80)**
    - → **ARDL model for cointegration testing**

$$\Delta ln\,GDP_t = \alpha_0 + \sum_{i=1}^{n} \alpha_1\,\Delta ln\,GDP_{t-i} + \sum_{i=1}^{n} \alpha_2\,\Delta ln\,NRE\_EC_{t-i} + \sum_{i=1}^{n} \alpha_3\,\Delta ln\,RE\_EC_{t-i} + \sum_{i=1}^{n} \alpha_4\,\Delta ln\,K_{t-i}$$

$$+ \lambda_1 lnGDP_{t-1} + \lambda_2 lnNRE\_EC_{t-1} + \lambda_3 lnRE\_EC_{t-1} + \lambda_4 lnK_{t-1} + u_t$$

4. Results

• Unit root test_ADF

10%: *, 5%: **, 1%: ***

Country	Variables	Level. Statistics	Diff. Statistics	Stationarity
Canada	GDP	-0.758	-4.278***	I(1)
	NRE_EC	-1.787	-3.659**	I(1)
	RE_EC	-1.175	-6.734***	I(1)
	K	-0.700	-4.835***	I(1)
China	GDP	-0.123	-3.287**	I(1)
	NRE_EC	0.807	-2.971*	I(1)
	RE_EC	0.159	-4.744***	I(1)
	K	-0.758	-3.308**	I(1)
Denmark	GDP	-2.404	-4.281***	I(1)
	NRE_EC	1.415	-2.875*	I(1)
	RE_EC	-4.376***	-3.648**	I(0)
	K	-1.282	-4.912***	I(1)
Germany	GDP	-1.064	-5.192***	I(1)
	NRE_EC	1.290	-4.087***	I(1)
	RE_EC	-2.224	-4.171***	I(1)
	K	-0.630	-4.945***	I(1)
India	GDP	3.594	-4.273***	I(1)
	NRE_EC	-0.284	-4.601***	I(1)
	RE_EC	-0.785	-4.661***	I(1)
	K	0.979	-5.686***	I(1)
Spain	GDP	-1.728	-2.431'	>I(1)
	NRE_EC	-1.907	-3.061**	I(1)
	RE_EC	-1.246	-6.176***	I(1)
	K	-1.303	-3.038**	I(1)
USA	GDP	-1.796	-4.071***	I(1)
	NRE_EC	-2.223	-4.678***	I(1)
	RE_EC	-2.089	-6.096**	I(1)
	K	-1.423	-3.460**	I(1)

4. Results

• Unit root test_PP

10%: *, 5%: **, 1%: ***

Country	Variables	Level. Statistics	Diff. Statistics	Stationarity
Canada	GDP	-0.768	-4.219***	I(1)
	NRE_EC	-1.884	-3.659**	I(1)
	RE_EC	-1.246	-6.982***	I(1)
	K	-0.770	-4.879***	I(1)
China	GDP	-0.139	-3.403**	I(1)
	NRE_EC	0.435	-3.007**	I(1)
	RE_EC	-0.033	-4.802***	I(1)
	K	-0.681	-3.362**	I(1)
Denmark	GDP	-2.268	-4.352***	I(1)
	NRE_EC	0.735	-2.777*	I(1)
	RE_EC	-4.210***	-3.809***	I(0)
	K	-1.317	-4.959***	I(1)
Germany	GDP	-1.186	-5.192***	I(1)
	NRE_EC	0.470	-4.172***	I(1)
	RE_EC	-1.871	-4.288***	I(1)
	K	-0.636	-4.903***	I(1)
India	GDP	4.111	-4.287***	I(1)
	NRE_EC	-0.298	-4.763***	I(1)
	RE_EC	-0.789	-4.556***	I(1)
	K	0.912	-5.715***	I(1)
Spain	GDP	-1.396	-2.590'	>I(1)
	NRE_EC	-1.718	-3.019**	I(1)
	RE_EC	-1.257	-6.175***	I(1)
	K	-1.404	-3.127**	I(1)
USA	GDP	-1.699	-4.000***	I(1)
	NRE_EC	-2.124	-4.768***	I(1)
	RE_EC	-2.354	-6.141***	I(1)
	K	-1.402	-3.399**	I(1)

4. Results

• Unit root test_KPSS

10%: ', 5%: *, 2.5%: ** 1%: ***

Country	Variables	Level. Statistics	Diff. Statistics	Stationarity at
Canada	GDP	0.0922	0.0717	Level and Diff.
	NRE_EC	0.239***	0.0408	Diff.
	RE_EC	0.196**	0.0246	Diff.
	K	0.114	0.0871	Level and Diff.
China	GDP	0.0854	0.0605	Level and Diff.
	NRE_EC	0.177**	0.118'	Diff.
	RE_EC	0.0554	0.0589	Level and Diff.
	K	0.0954	0.0659	Level and Diff.
Denmark	GDP	0.214**	0.0524	Diff.
	NRE_EC	0.248***	0.0424	Diff.
	RE_EC	0.244***	0.0685	Diff.
	K	0.162*	0.0456	Diff.
Germany	GDP	0.208**	0.0359	Diff.
	NRE_EC	0.159*	0.0761	Diff.
	RE_EC	0.242***	0.0897	Diff.
	K	0.152*	0.0616	Diff.
India	GDP	0.26***	0.043	Diff.
	NRE_EC	**0.133'**	**0.15***	**Level**
	RE_EC	0.17*	0.0941	Diff
	K	0.219***	0.0851	Diff
Spain	GDP	0.201**	0.0881	Diff
	NRE_EC	**0.213****	**0.125'**	**Diff**
	RE_EC	0.212**	0.0887	Diff
	K	0.177**	0.0737	Diff
USA	GDP	0.205**	0.0589	Diff
	NRE_EC	0.254***	0.109	Diff
	RE_EC	0.195**	0.0739	Diff
	K	0.165*	0.06	Diff

4. Results

- ## Cointegration test

10%: *, 5%: **, 1%: ***

	Johansen cointegration test		ARDL Bounds testing	
Country	**Statistic**	**Result**	**Statistic**	**Result**
Canada	57.6499*** 34.5067**	Rank 0 (1%) Rank 1 (5%)	2.196	No levels relationship
China	53.1831***	Rank 0 (1%, 5%)	3.804	No levels relationship
Denmark	45.9873***	Rank 0 (1%, 5%)	2.924	No levels relationship
Germany	60.6732*** 22.9393**	Rank 0 (1%) Rank 1 (5%)	5.716**	Relationship exist
India	58.4230*** 25.3194**	Rank 0 (1%) Rank 1 (5%)	5.044**	Relationship exist
Spain	33.1724***	Rank 1 (1%, 5%)	1.298	No levels relationship
USA	39.0330*** 17.6468**	Rank 1 (1%) Rank 2 (5%)	12.136***	Relationship exist

	5% critical	1% critical		I(0)	I(1)
Rank 0	54.64	61.21	1%	5.333	7.063
Rank 1	34.55	40.49	5%	3.710	5.018
Rank 2	18.17	23.46	10%	3.008	4.150

4. Results

• Cointegration test

10%: *, 5%: **, 1%: ***

Country	ARDL bounds test	Long-run	Approach
Canada	**No cointegration** (*conflict with Johansen at 5%)	X	VAR
China	**No cointegration**	X	VAR
Denmark	**No cointegration**	X	VAR
Germany	**Cointegrated at** 5% significance level	O	VECM
India	**Cointegrated at** 5% significance level	O	VECM
Spain	**No cointegration** (*conflict with Johansen)	X	VAR
USA	**Cointegrated at** 1% significance level	O	VECM

4. Results

- ## Causality test_VAR model

10%: *, 5%: **, 1%: ***

Country	H_o	Short-run		Results
Canada	GDP → RE_EC	7.6514	X	RE_EC → GDP
	RE_EC → GDP	10.346**	O	
China	GDP → RE_EC	54.93***	O	GDP ⇔ RE_EC (bi-directional)
	RE_EC → GDP	23.09***	O	
Denmark	GDP → RE_EC	9.0028*	O	GDP → RE_EC
	RE_EC → GDP	6.1744	X	
Spain	GDP → RE_EC	132.73***	O	GDP ⇔ RE_EC (bi-directional)
	RE_EC → GDP	45.264***	O	

4. Results

- ## Causality test_VECM model

10%: *, 5%: **, 1%: ***

Country	H_o	Short-run		Long-run(ECT_{t-1})	
Germany	GDP → RE_EC	0.8	X	4.99**	O
	RE_EC → GDP	0.05	X	4.54**	O
India	GDP → RE_EC	0.08	X	5.4**	O
	RE_EC → GDP	3.08*	O	0.02	X
USA	GDP → RE_EC	1.91	X	10.51***	O
	RE_EC → GDP	2.91	X	6.64***	O

- ✓ Germany: bi-directional causality in long-run
- ✓ India: RE_EC granger cause GDP in short-run
  GDP granger cause RE_EC in long-run
- ✓ USA: bi-directional in causality in long-run

5. Conclusion

- **Growth hypothesis and renewable electricity consumption**
  - ✓ **Empirical results (ARDL, Granger)**
    - → **Only 3 of 7 countries have long-run relationship**
    - → **Renewable granger cause GDP**
      Short-run: Canada, China, Spain, India
      Long-run: Germany, USA
    - → **Growth hypothesis? Canada, India only short-run**

  - ✓ **Renewable, Economic growth and Policy**
    - → **Economic growth can be opportunity**
    - → **Long-run perspective**
    - → **GDP to electricity consumption**
      Upbringing strategy → sustainable development
      (short-run)   (Long-run)

THANK YOU
FOR LISTENING

ANY QUESTIONS?