Why complex — Unique feature

v. technical — modern life / innovation

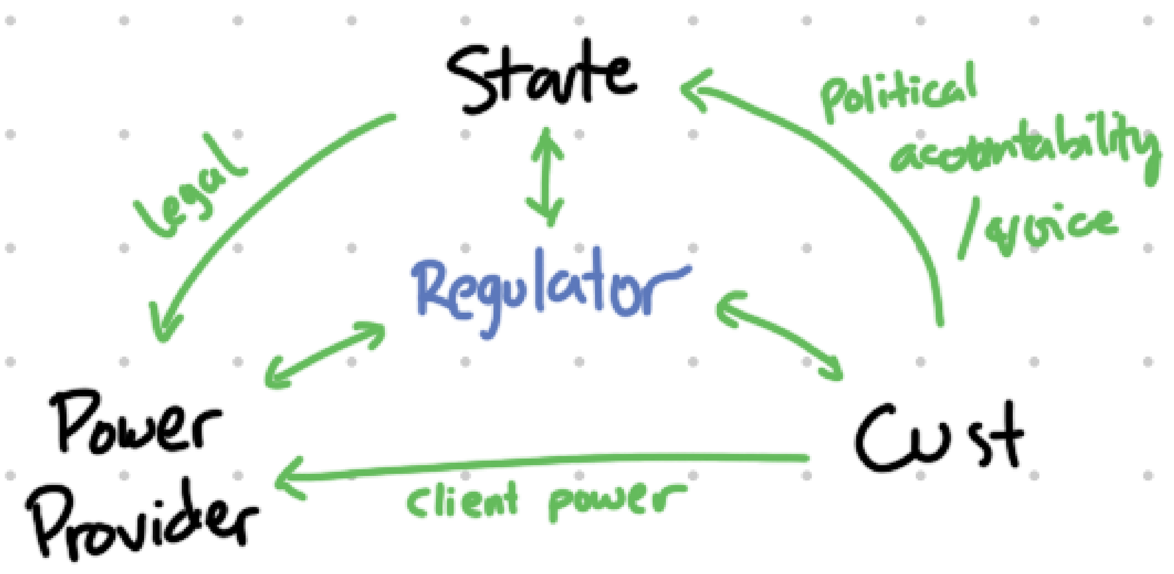
specific — concentrated location

many layer — essential to all eco activity / large externalities

$Y = A\,F(L, K)$

Trilema
- Sustainability → environment
- Reliability → E security
- Affordability → eco

E regulation
- principle : independence, transparent, secure
- tools & resource : laws, financial sup., HQ staff
- functions



Power syst — monopoly / single buyer / wholesale comp / retail comp

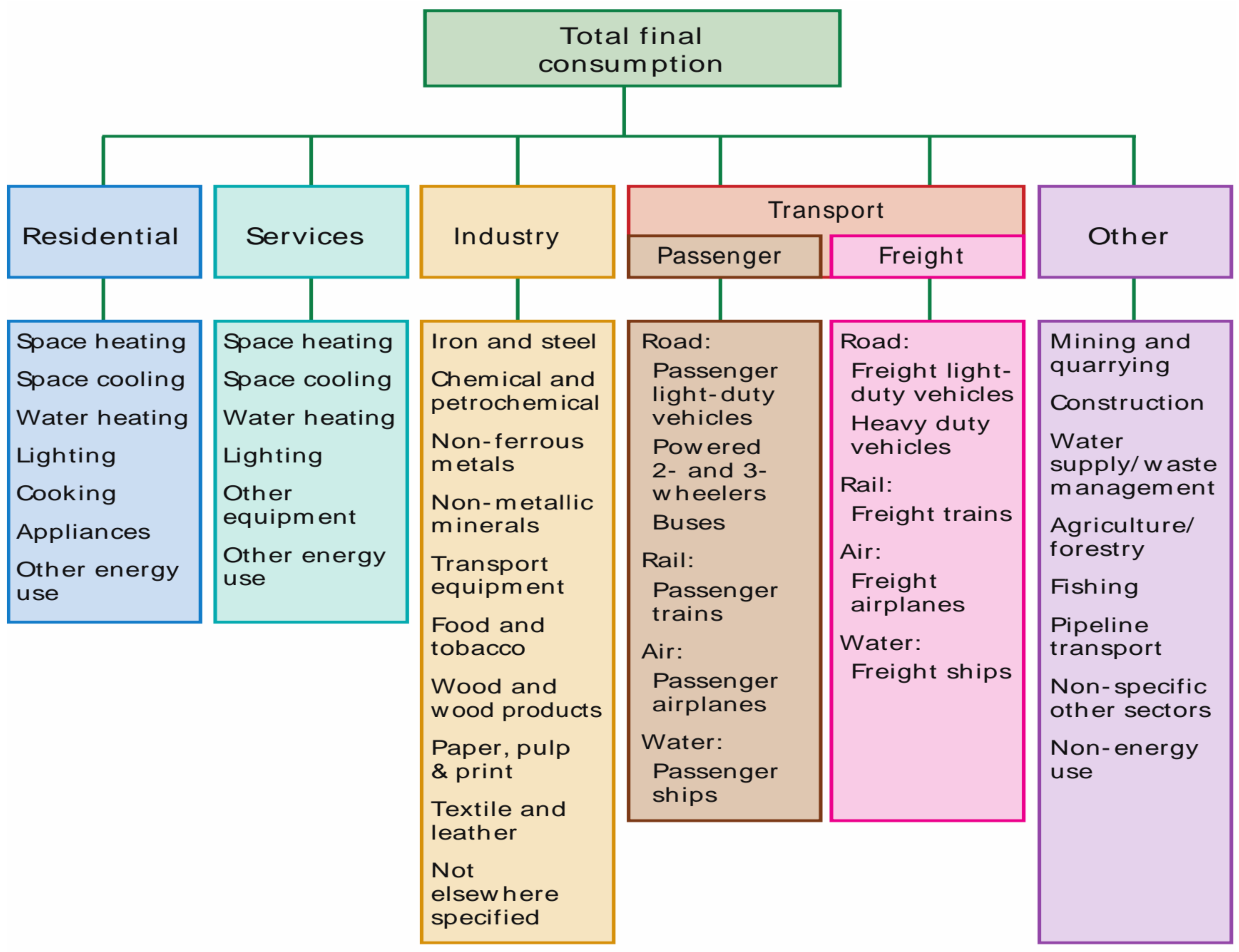
Gen → Wholesale → Transmission → Distribution → Retail

#2

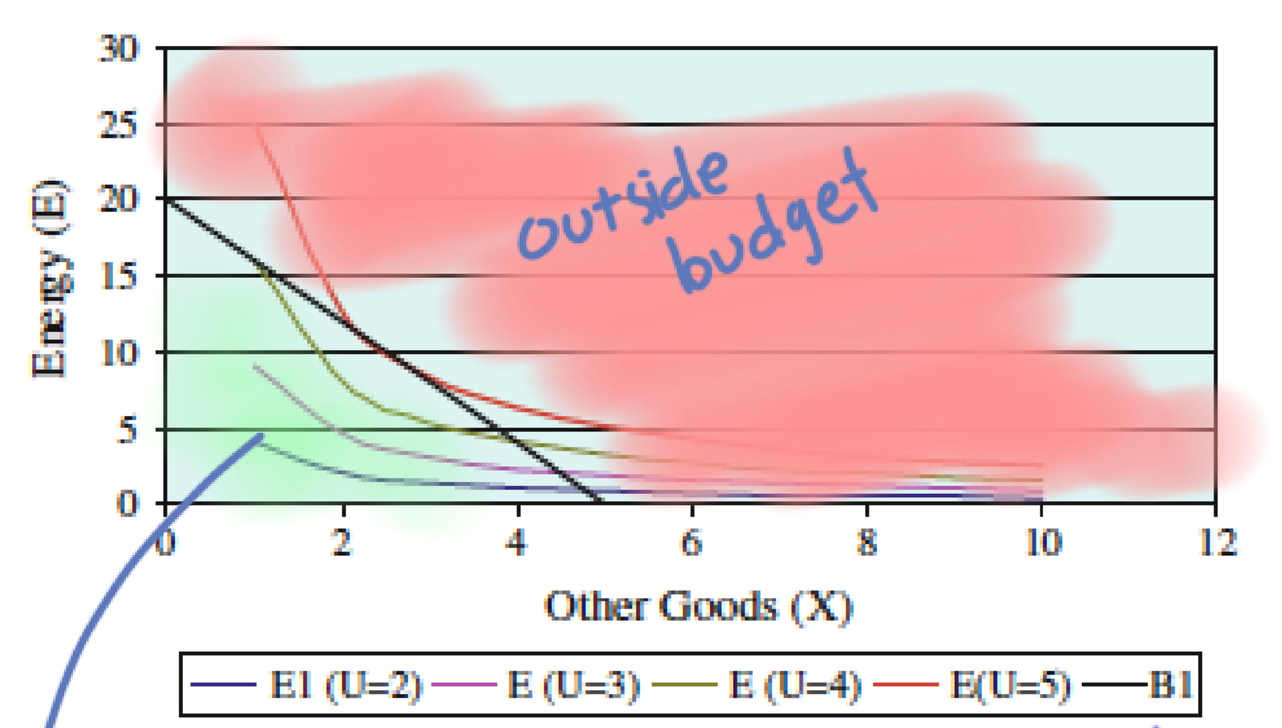
- E & eco → interdependance
- Effect of M-eco to E — lvl ecoact
  - interdependence
  - structure ecoad
  - technical compos.
  - institutional arr
  - M-management of eco & interaction w/

- E demand → arises from need, met through use of appliances
- " indicators
  - TFC per GDP
  - Sectoral E intensity
  - End-use
  - Unit E consumption
  - more data

cause of E final consmt yearly change —
- activity
- structural
- efficiency



- Budget constraint
  - consider budget $100 = 5E + 20X$
  - utility eq $U = E^{0.5} \cdot X^{0.5}$



$$\underset{\text{output}}{Q} = F(\underset{\text{capital}}{K}, \overset{\text{labor}}{L}, \underset{\text{energy}}{E}, \overset{\text{material}}{M})$$

complement (↑↓ or ↓↑)

Consumption Theory

$$C = b_0 + b_1 \cdot Y_d + u$$

C: consumer's expenditure X
Y_d: consumer's disposable (after-tax) income
b_0, b_1: unknown parameters
u: random disturbance or error

Based on the COBB-DOUGLAS production function:

$$E = a\frac{Y^{\alpha}}{P^{\beta}}$$

E: Energy Demand
Y: Income (GDP per capita)
P: Energy Price
a: coefficient

Consumer Demand Theory

$$D_X = b_0 + b_1 \cdot P_X + b_2 \cdot Y + b_3 \cdot P_Z + u$$

D_x: quantity demanded of the commodity X
P_x: price of the commodity X
Y: consumer's disposable (i.e. after tax) income
P_z: price of another (related) commodity Z

α: Income Elasticity of Energy Demand

$$\alpha = \frac{\Delta E/E}{\Delta Y/Y} = \frac{\%\ change\ in\ E}{\%\ change\ in\ Y}$$

β: Price Elasticity of Energy Demand

$$\beta = \frac{\Delta E/E}{\Delta P/P} = \frac{\%\ change\ in\ E}{\%\ change\ in\ P}$$

April, 7 '05

The following equations provide examples of specifications used in simple econometric analyses. E is energy consumption, Y is income (GDP), P is price, POP is population, EMP is employment of labour, a, b, c, d, e, f, - are coefficients to be determined through the estimation process, t is time period t while t-1 represents the time period before t.

(a) Linear relation between energy and income (GDP)
$E_t = a + bY_t$

This implies an (income) elasticity that tends asymptotically to unity as income increases. Note that b is not the elasticity in this specification, which has to be determined from the basic definition of elasticity.[21]

(b) Log-linear specification of income and energy
$\ln E_t = \ln a + b \ln Y_t$
Here b represents the elasticity of demand, which is a constant by specification.

(c) Linear relation between energy and price and income variables
$E_t = a + bY_t + cP_t$
This is not a popular specification however.

(d) Log-linear specification of income, price and energy
$\ln E_t = \ln a + b \ln Y_t + c \ln P_t$

As with model (b), the short-run price and income elasticities are directly obtained here.

(e) Dynamic version of log-linear specification of energy with price and income variables

End-use (engineering) model

Energy Demand for each activity results from the product of two factors: *LEVEL OF ACTIVITY* (energy service) and *ENERGY INTENSITY* (energy use per unit of service)

$$Energy\ use = \sum_{i=1}^{n} Q_i \cdot I_i$$

Q_i: Quantity of energy service i
I_i: Intensity of energy use for energy service i

$$Q_i = N_i \cdot P_i \cdot M_i$$

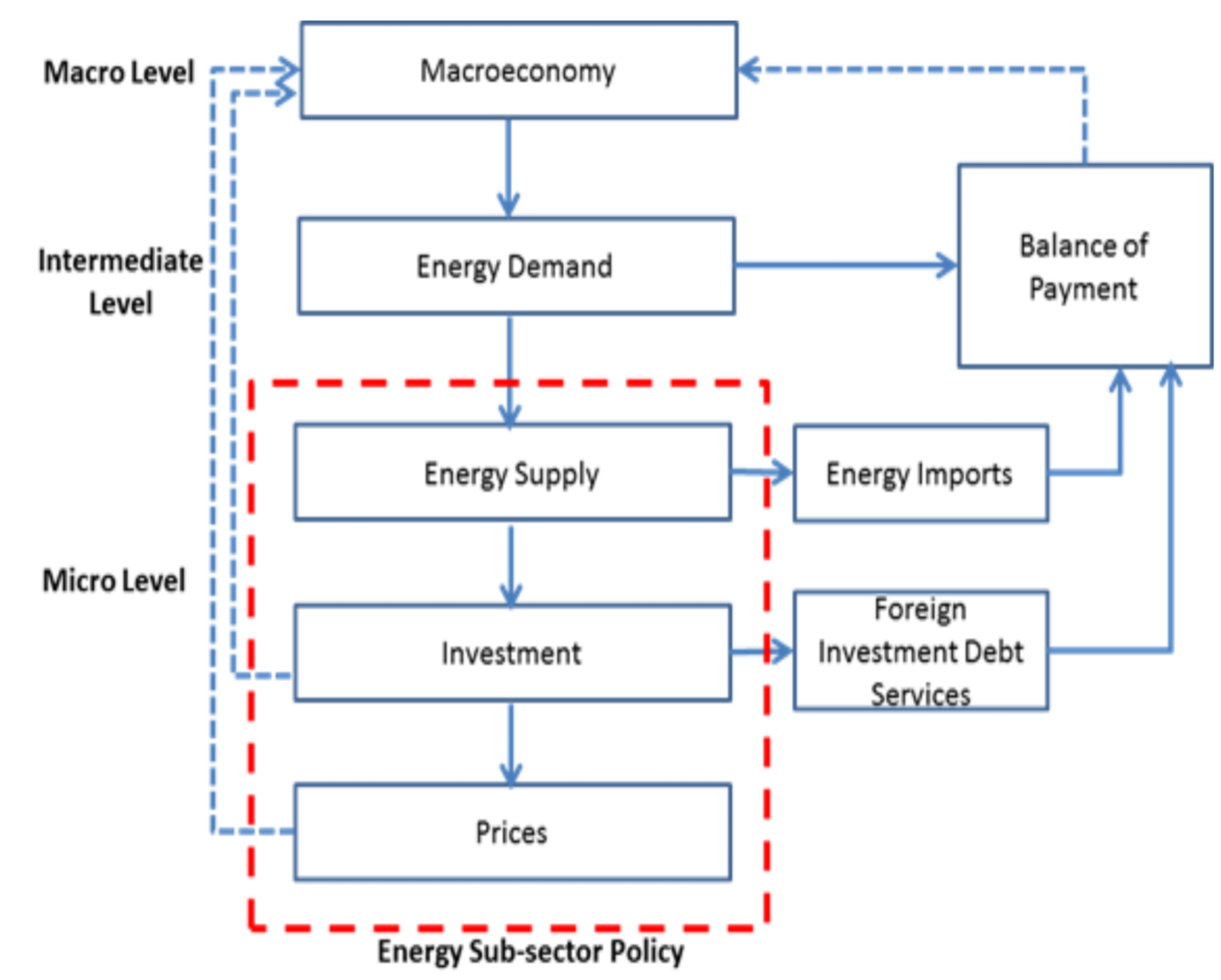
N_i: Number of eligible customers for end-use i

P_i: Penetration (total units/total customers) of end-use service i (can be >100%)

M_i: Magnitude of extent of end-use service i

#3

- $\mathcal{E}$ eco → where eco principle & tools are applied
  to analyse logically & systematically,
  and develop well-informed understanding
  of the issue



- $\mathcal{E}$ scarcity indicators
  - engrg
  - eco
  - tecgical chg

- m-eco → $\mathcal{E}$ supply - demand
- M-eco → invstm, fin.cing, eco-linkage

• Bottom-up → m-eco approach → detailed data gathering → more accurate	• Top-down → M-eco approach → effect of GDP & reg on $\mathcal{E}$ demand → more of a prediction

KEN

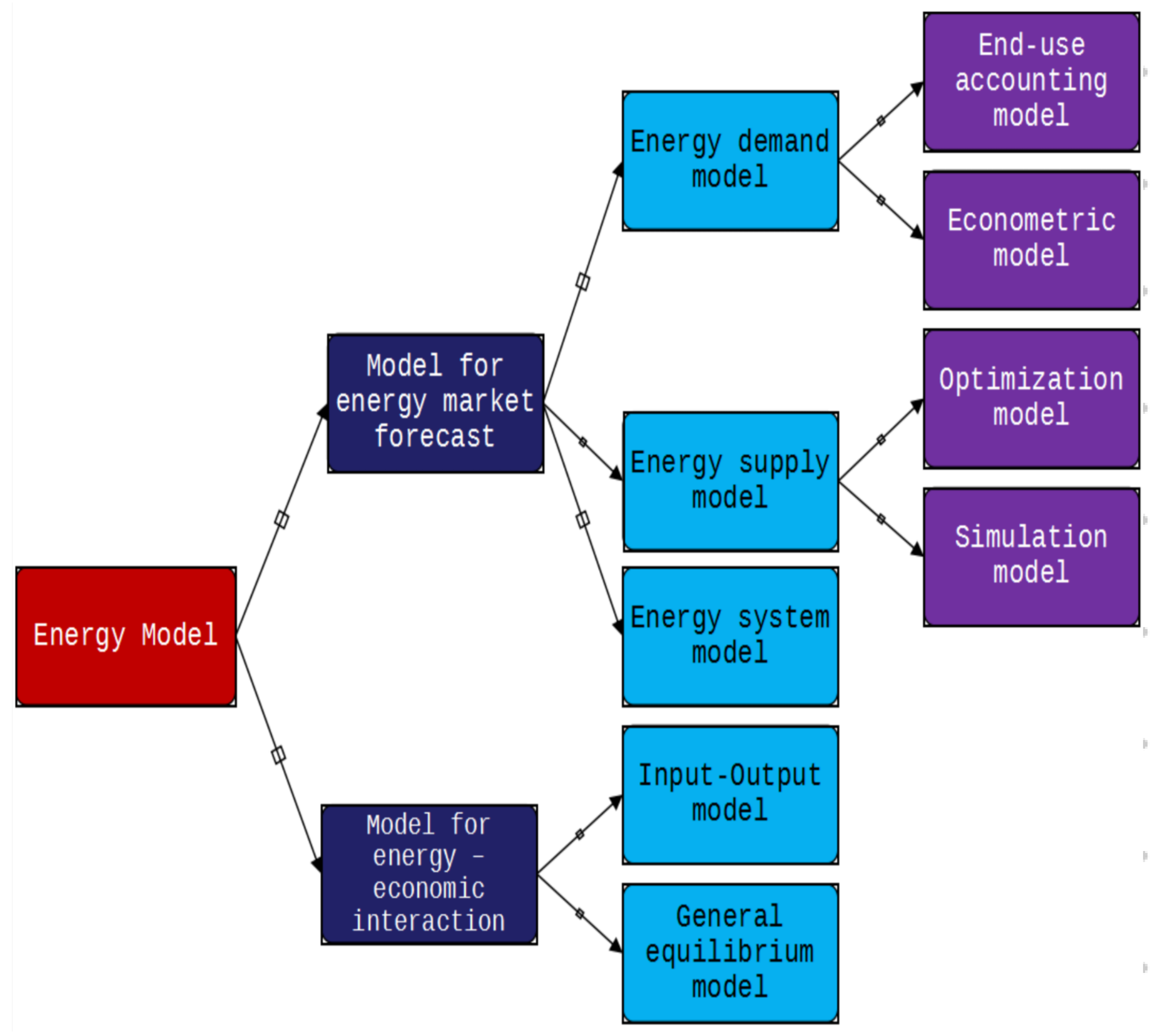
- Problem
  - eco : innacurate subsidy, $\mathcal{E}$prize ≠ ecoprice, low invsm
  - techgy & innov : infrastructure, few research
  - access to $\mathcal{E}$
  - regulation & management

- KEN's purpose → $\mathcal{E}$ independence & resillience to support SND (sust natl. dev)

- Target : 1) Paradigm change 2) $\mathcal{E}$ elasticity (<1) 3) $\mathcal{E}$ intensity (↓1%) 4) e^s ratio 5) gas in household 6) $\mathcal{E}$ mix

- $\mathcal{E}$ modelling consideration
  - $\mathcal{E}$ supply qty
  - $\mathcal{E}$ system + impact
  - assesment criteria

classification:



Demand

m-lvl

$$X_{energi} = f(\overset{\ominus}{P_{energi}}, \overset{\oplus}{P_{other}}, \overset{\oplus}{I})$$

M-lvl

$$X_{energi} = g(GDP, \text{inflasi}, \text{populasi})$$

Supply

$$\left.\begin{aligned} &\text{min cost} = \underset{\text{cap cost}}{r}K + \underset{\text{labor wage}}{w}L \\ &\text{st} \quad \bar{Q} = f(K, L) \end{aligned}\right\} \begin{aligned} K^* &= f(r, w, \bar{Q}) \\ L^* &= f(r, w, \bar{Q}) \end{aligned}$$

max profit

$$\max \pi = \overset{\text{price}}{P(Q)} \cdot \overset{\text{qty sold}}{Q} - rK^* - wL^*$$

$$Q = f(r, w, P) \longrightarrow \underset{\text{eceran}}{Q_{energi}} = g(P_{input}, P_{output})$$

M-lvl

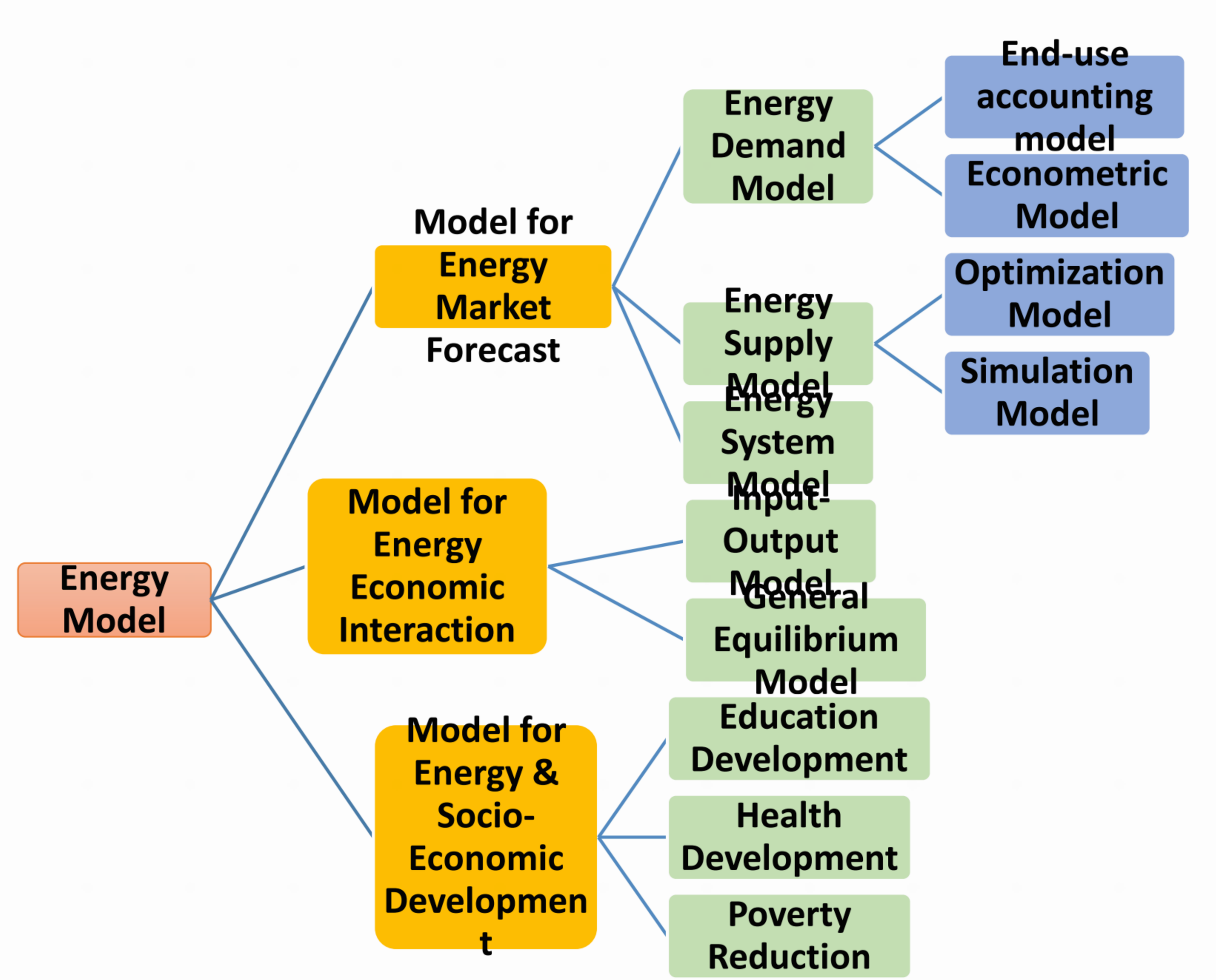
$$S_x = g(P_x, P_{input}, \text{investment}, \ldots)$$

#5

Model → Persamaan yg mendeskripsikan suatu sistem

- Stochastic — ekonometrika → proyeksi; tanpa info mengenai struktur eko — time series / cross section / panel/pool
  - DSGE
- Non-Stochastic — Optimisasi
  - Keseimbangan umum → "Bagaimana jika" / "Perkiraan dampak" — Input-Output (IO) / Social Accounting Matrix (SAM) / CGE (Computable General Equil) / DRCGE / DSGE
    - → Model Dampak Luas Ekonomi --> multi-sektoral
- Qualitative

Klasifikasi Model Energi



Input-Output
- Output multiplier
- Forward linkage
- Backward linkage

SAM → matrix

	situation A	B	C
ε_1	implementation effect of ε_1 in A		
ε_2	~ ε_2 in A		
ε_3	~ ε_3 in A		

CGE → market interaction
↳ effect of A's market to B's market?

Modern energy consumption in Indonesia: Assessment for accessibility and affordability

$$Ln\_EE_i = \beta_0 + \beta_1 * Ln\_NEE_i + \beta_2 * LPA_i + \beta_3 * ELA_i + \sum_j \beta_j * EA_{ji} + \sum_l \beta_l * X_{li} + \sum_k \beta_k * \alpha_{ki} + \varepsilon_i$$

multiple linear regression

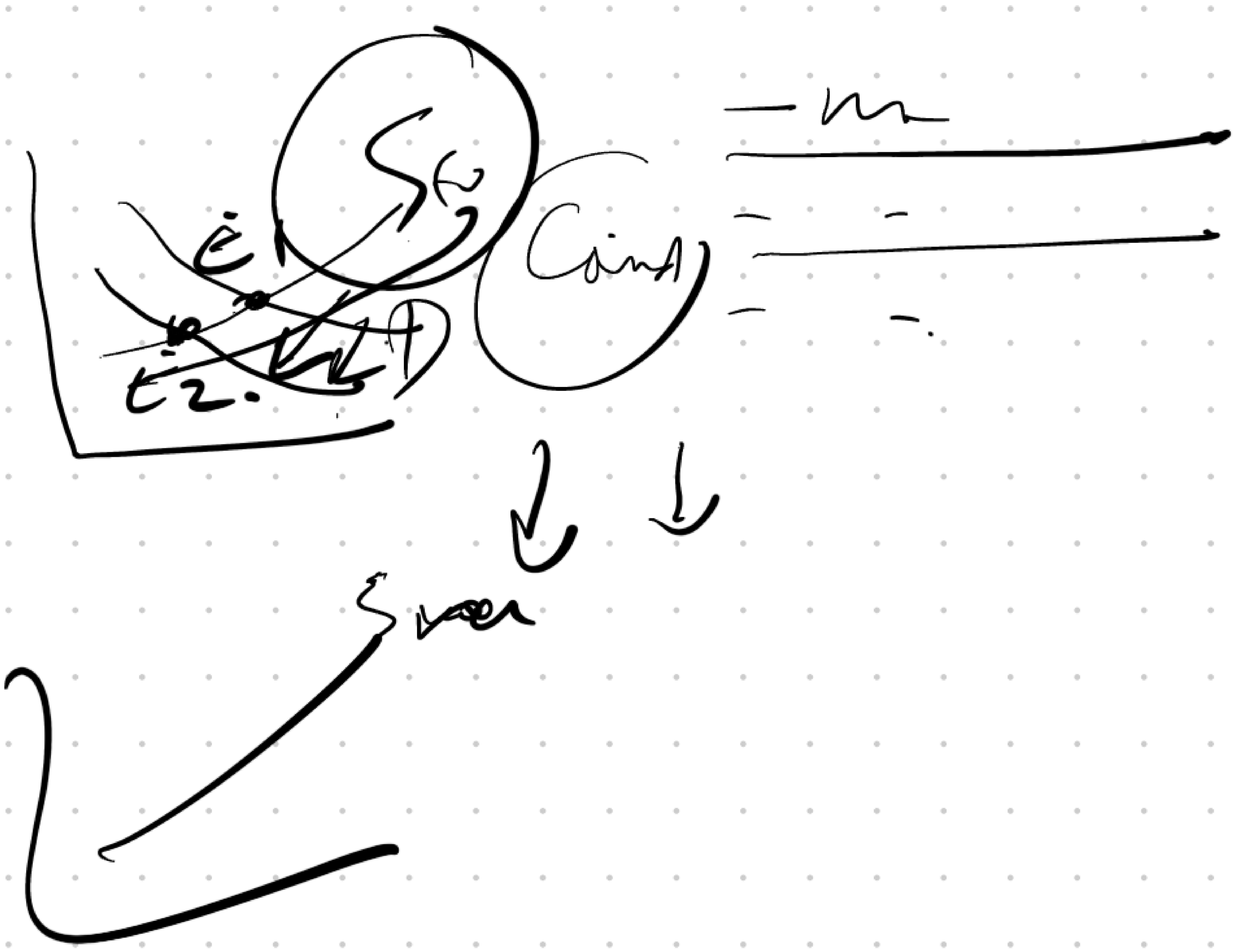
Variable explanations.

Variables	Explanation	Units
Dependent variable		
Ln_EE	Energy expenditure (in natural logarithm) Household total energy spending	IDR
Independent variable/main variables		
Ln_NEE	Non-energy expenditure (in natural logarithm) Subtraction of the household total expenditure and the total number of energy expenditure in a year	IDR
LPA	LPG accessibility 1 = household use LPG, 0 = household does not use LPG	Dummy
ELA	Electricity accessibility 1 = household use electricity, 0 = household does not use electricity	Dummy
Other energy accessibility (EA)		
CGA	City-gas accessibility 1 = household use city-gas, 0 = household does not use city-gas	Dummy
KEA	Kerosene accessibility 1 = household use kerosene, 0 = household does not use kerosene	Dummy
GEA	Generator's fuel accessibility 1 = household use generator's fuel, 0 = household does not use the generator's fuel	Dummy
CCA	Charcoal accessibility 1 = household use charcoal, 0 = household does not use charcoal	Dummy
FWA	Firewood accessibility 1 = household use firewood, 0 = household does not use firewood	Dummy
Control variables (X)		
HHM	Household members Total number of household members	Person
HHA	Head of household's ages Age of head of household	Years
HHG	Head of household's gender 1 = male, 0 = female	Dummy
EDU	Head of household's education 1 = head of a household have a secondary school degree or above, 0 = other	Dummy
EMP	Head of household employment 1 = head of a household has a full-time occupation, 0 = other	Dummy
AGR	Head of household agriculture worker 1 = head of household works in the agricultural sector, 0 = other	Dummy
Ln_IFS	In-house floor size (in natural logarithm) Size of in-house floor	m2

Energy spending drivers at the national level in 2008.

2008	only Ln_nee data obtained	if lpa~fwa data also obtained						
obtained variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln_nee	β_1 0.615***	β_1 0.570***	β_1 0.517***	β_1 0.529***	0.526***	0.480***	0.480***	0.475***
	(0.000108)	(0.000126)	(0.000150)	(0.000149)	(0.000150)	(0.000156)	(0.000158)	(0.000159)
lpa		β_2 0.214***	0.224***	0.215***	0.215***	0.188***	0.187***	0.184***
		(0.000235)	(0.000234)	(0.000229)	(0.000229)	(0.000220)	(0.000222)	(0.000221)
eia		β_3 0.247***	0.253***	0.245***	0.245***	0.211***	0.211***	0.201***
		(0.000333)	(0.000334)	(0.000335)	(0.000335)	(0.000338)	(0.000338)	(0.000339)
cga		$\beta_{j,1}$ 0.318***	0.319***	0.310***	0.310***	0.286***	0.286***	0.284***
		(0.000831)	(0.000826)	(0.000810)	(0.000810)	(0.000799)	(0.000799)	(0.000797)
kea		$\beta_{j,2}$ 0.268***	0.257***	0.256***	0.256***	0.253***	0.253***	0.250***
		(0.000224)	(0.000219)	(0.000216)	(0.000216)	(0.000210)	(0.000210)	(0.000209)
gea		0.813***	0.815***	0.814***	0.813***	0.801***	0.801***	0.804***
		(0.000877)	(0.000873)	(0.000878)	(0.000877)	(0.000881)	(0.000881)	(0.000883)
cca		0.121***	0.109***	0.103***	0.102***	0.086***	0.086***	0.091***
		(0.000605)	(0.000604)	(0.000604)	(0.000604)	(0.000601)	(0.000602)	(0.000602)
fwa		0.043***	0.017***	0.003***	0.001***	−0.018***	−0.018***	−0.007***
		(0.000177)	(0.000175)	(0.000174)	(0.000174)	(0.000173)	(0.000175)	(0.000181)
hhm			$\beta_{l,1}$ 0.037***	0.036***	0.034***	0.030***	0.030***	0.030***
			(0.000051)	(0.000051)	(0.000051)	(0.000049)	(0.000050)	(0.000050)
hha				$\beta_{l,2}$ 0.004***	0.005***	0.003***	0.003***	0.004***
				(0.000005)	(0.000005)	(0.000005)	(0.000005)	(0.000006)
hhg					0.043***	0.038***	0.038***	0.033***
					(0.000222)	(0.000216)	(0.000216)	(0.000220)
Ln_ifs						0.143***	0.143***	0.145***
						(0.000129)	(0.000130)	(0.000130)
edu							0.004***	−0.001***
							(0.000172)	(0.000173)
emp								0.065***
								(0.000220)
agr								−0.052***
								(0.000162)
Obs	57,542,620	57,542,620	57,542,620	57,542,620	57,542,620	57,542,620	57,542,620	57,542,620
R-squared	0.430	0.472	0.477	0.485	0.486	0.499	0.499	0.501

All models use survey weights and include province-year (province-round) fixed effects. All models passed the sensitivity analysis. Robust standard errors in parentheses.
*** $p < 0.01$.



	S/E A	S/E B
E1	x^2	O U
E2	Y	P.
E3	Z	Q

100

6

prg kan eko-energi dipengaruhi byk hal → Penelitian Skrg → relation soc-eko
- penurunan emisi via carbon tax

Kebijakan
- UU 17/2007
- UU 30/2007 (E) → KEN (PP 79/2014)
- UU 30/2009 (e⁴)
- UU 11/2020 (ciptaker)

UU
- Migas 22/2001
- Minerba 3/2020
- Panas bumi 21/2014
- Nuklir 11/2007
- EBT RUU

- TKDN : ↑ output hulu
- Hilirisasi : Penyebaran output hilir

	'15	'23	NDC '25	LTC-LCCR '50	NZE '60
Bauran EBT	4%	13.09%	23%	31%	

Intensitas energi (brp energi utk produksi Rp 1.) → ↓ %

insentif → mendorong/membantu subsidi
disintentif → meningkatkan efisiensi (pressure)

KEN
- Peranan E dlm pembangunan — eko, kesehatan, pendidikan
- mencapai target SDG

- Akses energi yang terjangkau, andal, dan modern.
- Peningkatan pangsa EBT dan efisiensi energi.
- Kerja sama internasional.
- Pembenahan infrastruktur dan teknologi untuk akses bahan bakar yang bersih.

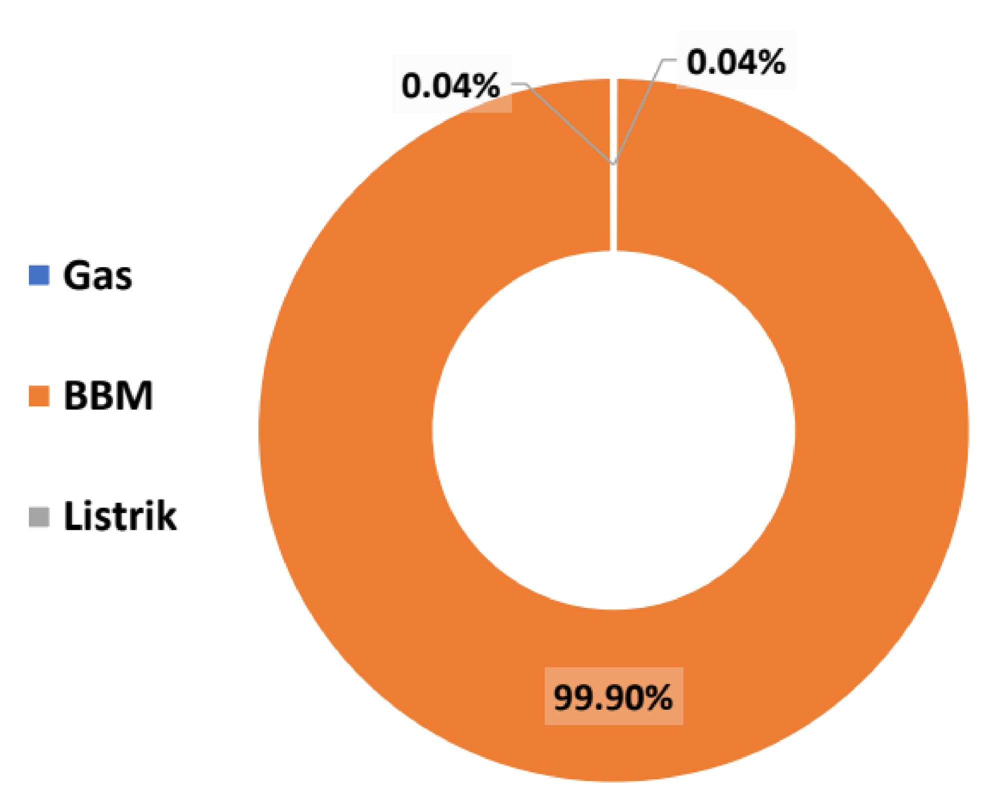
Transisi penggunaan energi konvensional ke EBT akan membantu memperlambat proses perubahan iklim.

Tantangan:
1. Distribusi energi bersih
2. Ketimpangan & kemiskinan energi
3. Bauran energi
4. Efisiensi energi
5. NZE/Pembangunan Rendah Karbon

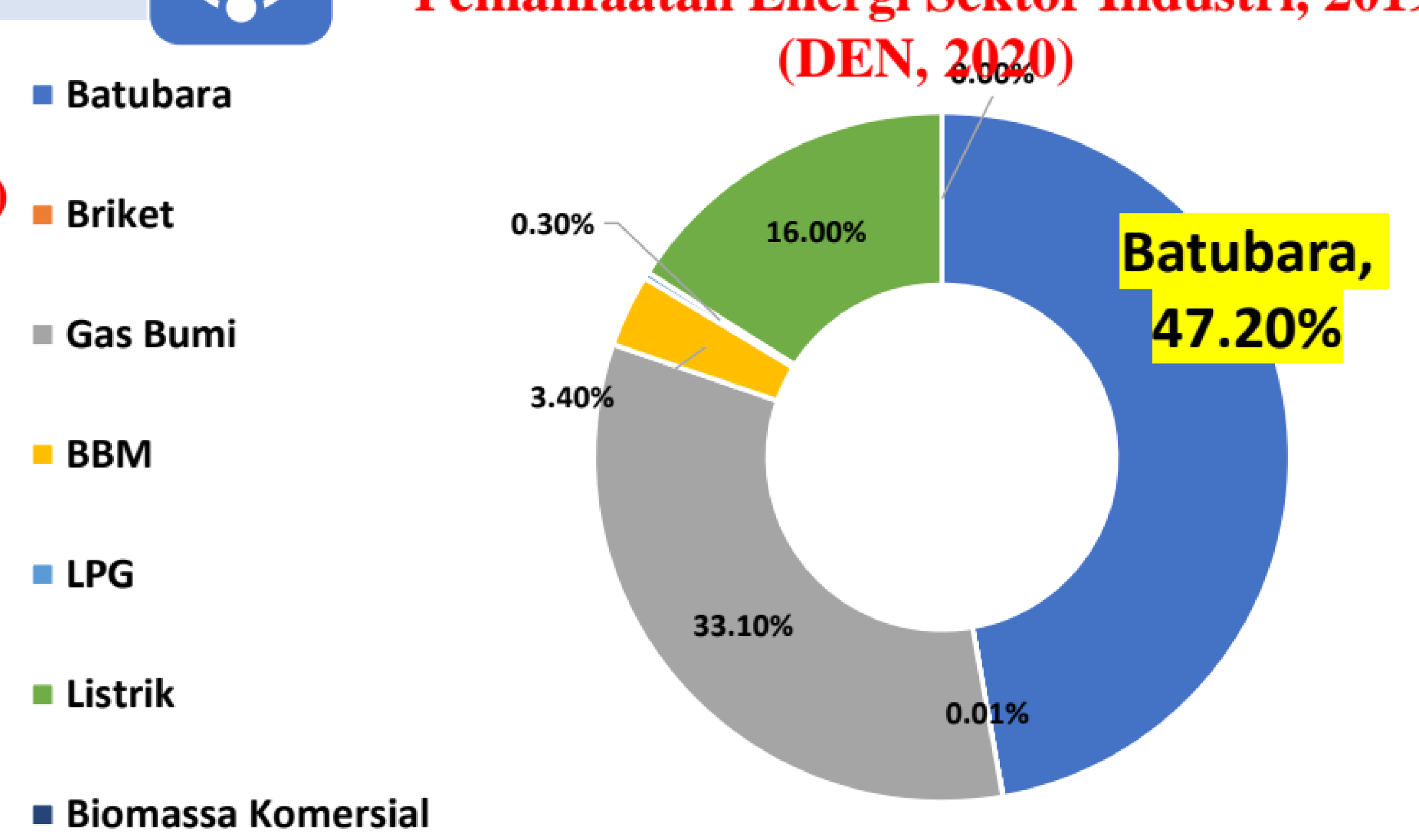
- 68% global emission from 10 countries → INA 1.88%
- Pengukuran emisi → Citra Satelit

3 Bauran Energi

Pemanfaatan Energi Sektor Transportasi, 2019 (DEN, 2020)



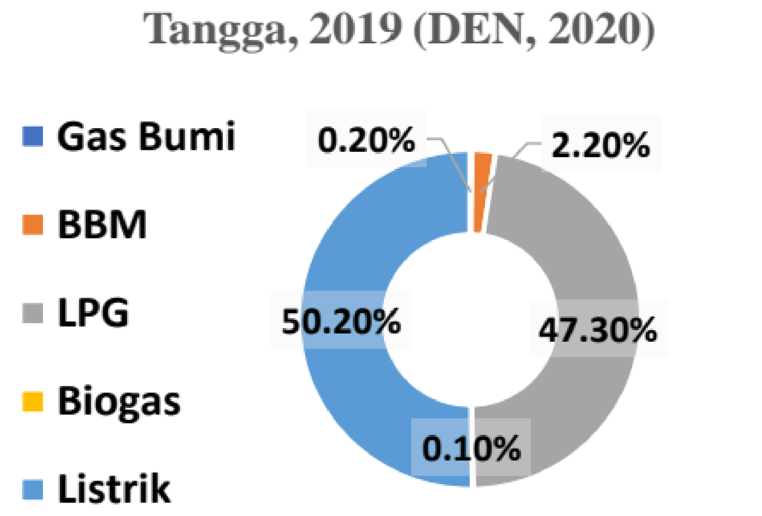
Pemanfaatan Energi Sektor Industri, 2019 (DEN, 2020)



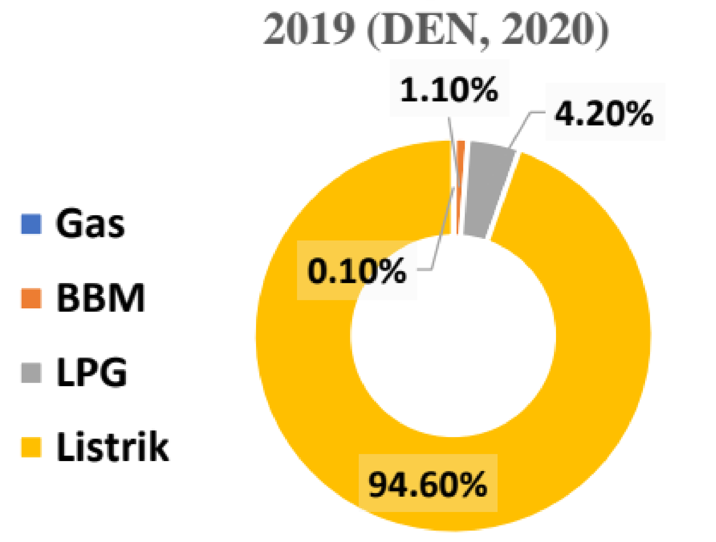
- Bauran final :

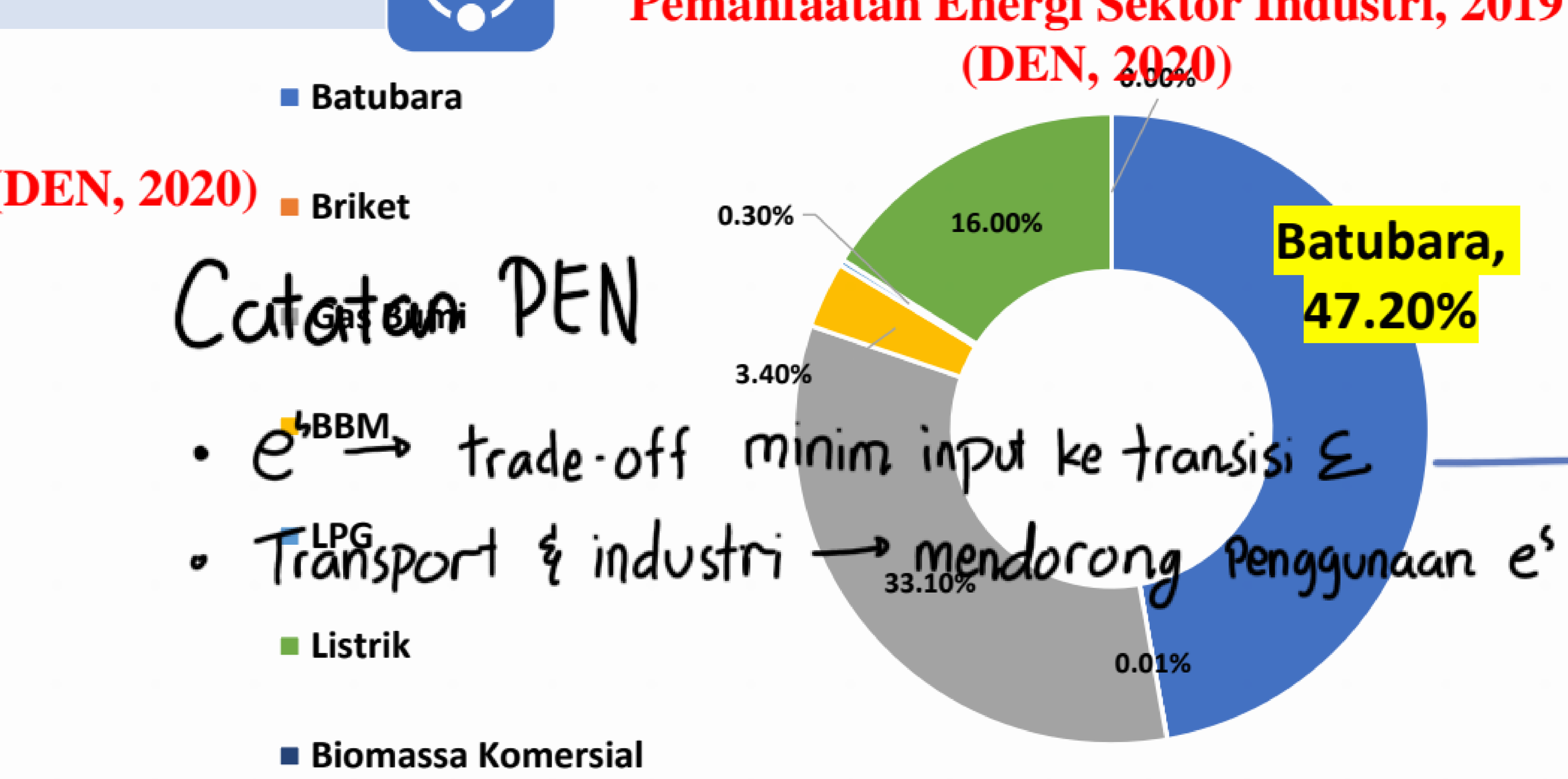
Seluruh sektor masih belum memanfaatkan penggunaan EBT secara optimal

Pemanfaatan Energi Sektor Rumah Tangga, 2019 (DEN, 2020)



Pemanfaatan Energi Sektor Komersial, 2019 (DEN, 2020)



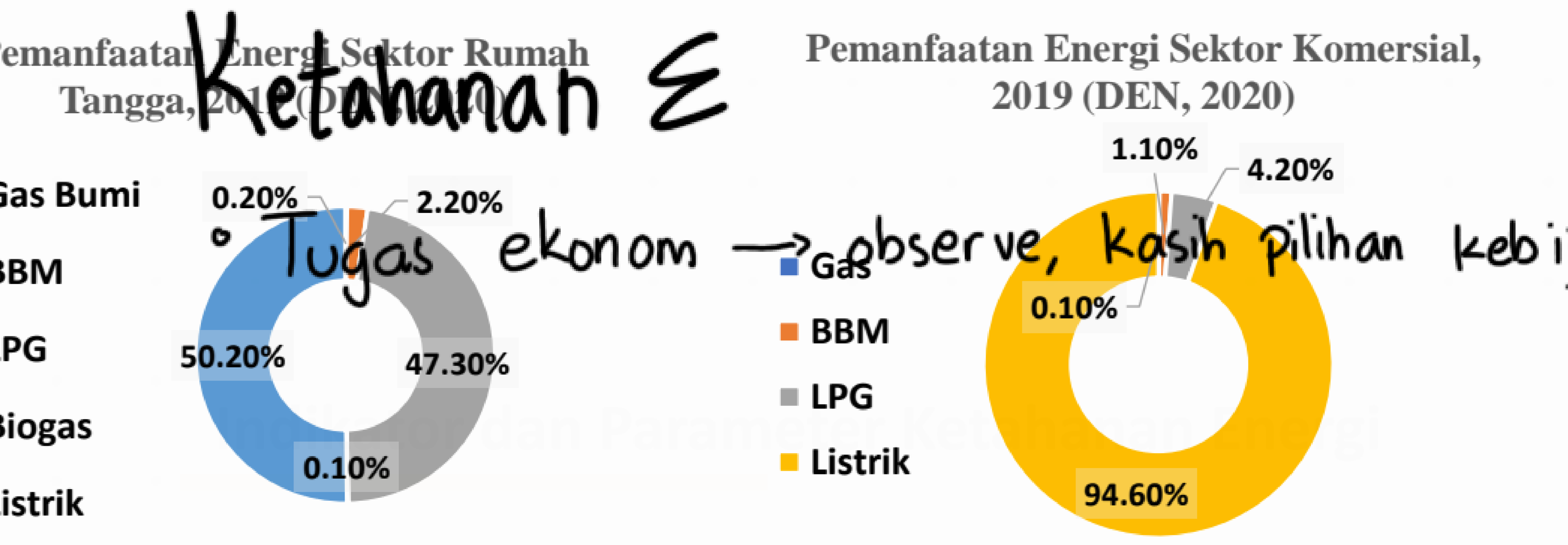


Catatan PEN

- e's → BBM, LPG trade-off minim input ke transisi E
- Transport & industri → mendorong Penggunaan e's

Conclusion

- multi-objective optimization
- bauran kebijakan



Ketahanan E

- Tugas ekonom → observe, kasih pilihan kebijakan yg dpt dipertimbangkan

- Aspek Affordability
  - Produktivitas Energi
  - **Harga BBM dan LPG**
  - Harga Listrik
  - Harga Gas Bumi
- Aspek Accessibility
  - Penyediaan & Layanan BBM
  - Penyediaan dan Layanan Listrik
  - Penyediaan dan Layanan Gas Bumi & LPG
- Aspek Availability
  - Keberlanjutan Cadangan Energi
  - Ketergantungan Impor Energi
  - DMO Energi
  - Cadangan Energi Nasional
- Aspek Acceptability
  - **Intensitas Energi** / Efisiensi Energi
  - **Peranan EBT**
  - Capaian Diversifikasi ke **Energi Bersih**
  - Penurunan **Emisi Karbon**

Klasifikasi Penilaian	Skala Nilai/Warna
Sangat Tahan (*Highly Resilience*)	8 - 10
Tahan (*Resilience*)	6 - 7,99
Kurang Tahan (*Less Resilience*)	4 - 5,99
Rentan (*Vulnerable*)	2 - 3,99
Sangat Rentan (*Highly Vulnerable*)	0 - 1,99

Setjen DEN, 2020

Tantangan

- Produksi migas ↓
- Optimisasi Minerba
- Pemanfaatan EBT → Transisi E
  - ↳ Single buyer (PLN)

Program

- Hilirisasi minerba
- DME (substitusi LPG)
- Transisi E

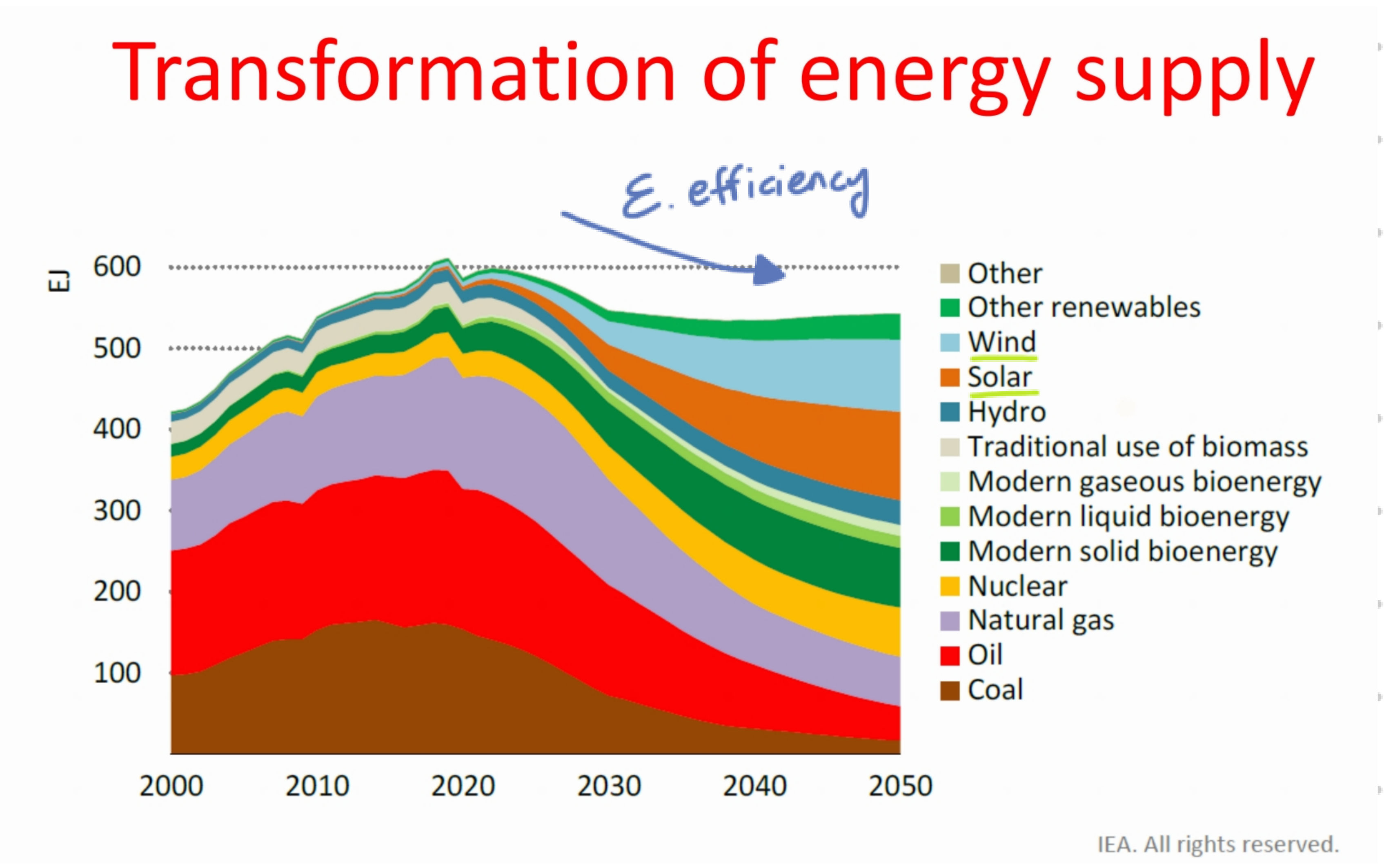
#7

F. Fuel → OPEC → Regulated Price

Coal ×

NatGas → . . . . . → Regional Price

RE
- Difficult to trade → lack of infrastructure
  - ↳ easier :
    - Biofuel
    - Hydrogen



Motivation

- Business supply depend on the market
- Cost : Resource , transport,

Characteristic of E Project (Battacharyya)

- High CapEx
- Asset Specificity
- Long-life of assets → uncertainity about future cost & benefit
- Long gestation period → long time to build

Cost {

Source { Renewable / Non-Renewable

Critical Material is prediction to have more competition compared to energy resource in the future

factor for E tech choice
- source
- demand
- tech progress
- physical env.

factors that affect price:
market demand & system

Energy technologies

Primary energy or Fuel → Energy Conversion → Final energy

Fossil fuels
Renewables
Nuclear

Energy technologies

Electricity
Heat/Cool
Transport fuel

Rule: 50H/30E/20T

Final Energy or Power Output from the Energy Conversion device:

$P = \eta \times F$; η = efficiency, F= 'fuel'
$\eta(\underline{X})$, $\underline{X}$= technical parameters

PHYS-E0483_ Peter Lund

Primary Energy Sources:
- Light Crude
- Heavy Oil
- Tar Sands
- Wet gas
- CBM
- Tight gas
- Nuclear
- Coal
- Solar
- Wind
- Biomass
- Hydro
- Geothermal

Extraction & Conversion Technologies:
- Exploration
- Deeper water
- Arctic
- LNG
- Refining
- Differentiated fuels
- Advantaged chemicals
- Gasification
- Syngas conversion
- Power generation
- Photovoltaics
- Bio-enzymatics
- H_2 production & distribution
- CO_2 capture & storage

End Use Technologies:
- ICEs
- Adv. Batteries
- Hybridisation
- Fuel cells
- Hydrogen storage
- Gas turbines
- Building efficiency
- Urban infrastructure
- Systems design
- Other efficiency technologies
- Appliances
- Retail technologies

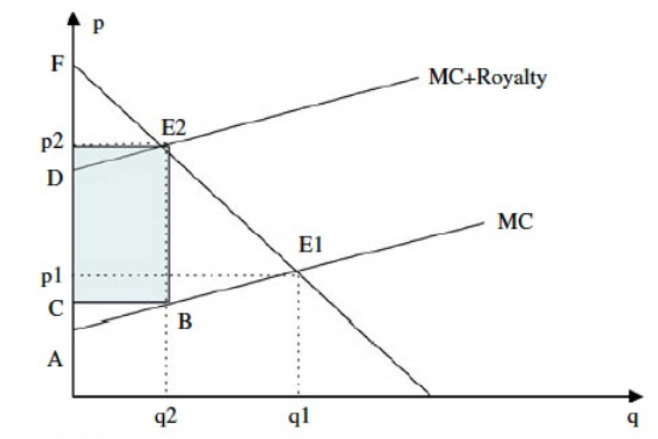
Eco of Fossil Fuel Supply

Non-renewable sources
- Oil, coal, natgas, nuclear

Resource rent
- **Mining rent**. Geological
- **Technological rent**
- **Positional rent**. Proximity to market
- **Quality rent**. Chemical/ Physical properties.
- Non-competitive market.

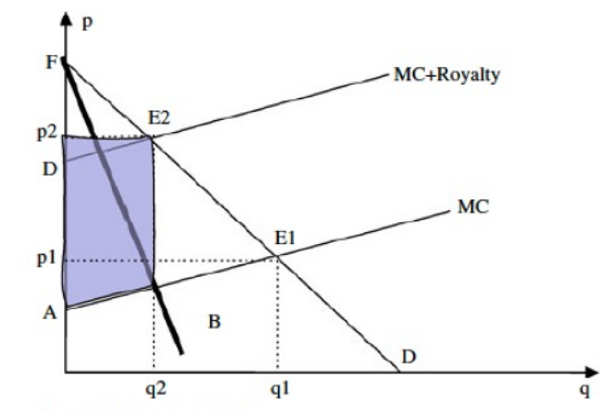
Effect of royalty and monopoly

Fig. 8.15 Effect of royalty



Case 1: Imposition of Royalty

Fig. 8.16 Nationalisation as a possible method of rent capture



Case 2: Monopoly pricing

Source: Bhattacharyya

What's Missing from the Classic Theory?

- Exploration: Reserves are an *inventory*; decisions to search, to prove, & to drill are intertemporal choices, like classic model.
  - End 1976 to end 2009, US proved reserves ↓ 10.26 B bbl.; production?
  - Production during that period was 78.45 B bbl.
- Depletion: Costs of finding, extracting likely to rise as more is produced from any given area (e.g., US).
- Innovation: Technologies for finding, extracting improve over time – a race with depletion.
- Uncertainty: Future demand, supply are not known.
- SR Inflexibility: Simple model over-states flexibility in output choice – little SR supply flex for oil + inelastic demand ⇒ SR P volatility.
- Cartel Behavior: OPEC behavior is complicated
- Politics: Why else drill miles deep, miles offshore when it is much cheaper to produce in the Middle East?

Source: MIT

Hotelling Theory: Timing of Decision
Finding the correct timing for highest opportunity cost

Eco of RE supply

Drivers:
- Reducing CO2, climate change mitigation
- Energy security
- Improving energy access
- Employment opportunities
- Spill-over effects

Carriers:
- Electricity (majority)
- Bioenergy, liq biofuels
- Biohydrogen
- Bio methane

Project characteristics:
- Low margin
- High risk

Electricity properties:
- Intermittent energy source (i.e. solar wind)
- no Storage / require one

Issues due to intermittent:
- intermittent e^s
- low capacity util
- require back up capacity

Electricity price: Regional -> no international trade