



IRPET

Istituto Regionale
Programmazione
Economica
della Toscana

IRPET *reef*: un modello biregionale Input-Output economico/energetico

Bologna, Ottobre 2019

Energy-economic flows: principio e corollario

Ogni modello EE deve rispettare il principio di conservazione dell'energia ossia:

In termini di modello I-O:

$$\alpha_{kj}x_j = \sum_{i=1}^n \alpha_{ki}z_{ij} + g_{kj}$$

k = prodotto energetico
j,i = settore

α_{kj} = fabbisogno totale del prodotto energetico *k-esimo* per una unità di output *j*

g_{kj} = fabbisogno diretto del prodotto energetico *k-esimo* per la produzione della quantità di output *j*

z_{ij} = input intermedio dal settore *i-esimo* al settore *j-esimo*

Corollario (in un sistema chiuso):

Totale prodotti energetici primari =

Totale prodotti energetici secondari

+ Perdite trasformazione

Modelli EE basati su Input-Output (pro e contro)

1. Approccio ibrido [Bullard and Herenden (1975)]

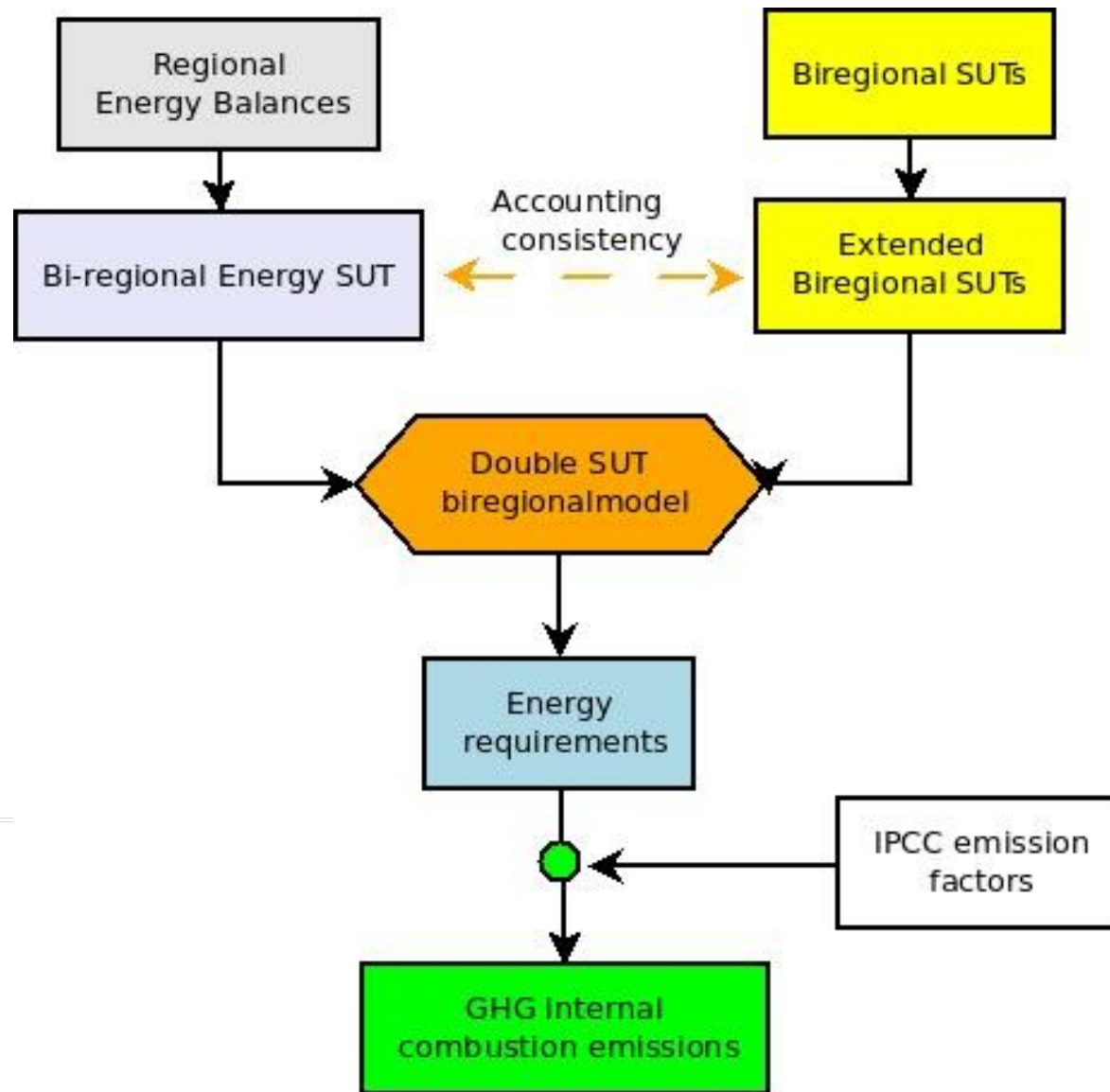
		Industries					Final demand	Total output	
		Energy		Non-energy					
		1	r	$r + 1$	\cdots	n			
Energy	1	e_{11}	\cdots	e_{1r}	$e_{1(r+1)}$	\cdots	e_{1n}	h_1	g_1
		\vdots	\ddots	\vdots	\vdots	\ddots	\vdots	\vdots	\vdots
	r	e_{r1}	\cdots	e_{rr}	$e_{r(r+1)}$	\cdots	e_{rn}	h_r	g_r
$r + 1$		$z_{(r+1)1}$	\cdots	$z_{(r+1)r}$	$z_{(r+1)}$	\cdots	$z_{(r+1)n}$	$f_{(r+1)}$	$x_{(r+1)}$
Non-energy	\vdots	\vdots	\ddots	\vdots	\vdots	\ddots	\vdots	\vdots	\vdots
	n	z_{n1}	\cdots	z_{nr}	$z_{n(r+1)}$	\cdots	z_{nn}	f_n	x_n
		Z^*					f^*	x^*	

2. Approccio dei coefficienti di fabbisogno diretto (DIC)

3. Approccio multifattoriale[[Guevara and Domingos (Energy Economics 2017)]

IRPET reef è costruito secondo l'approccio **MF modificato**

IRPET reef: catena di montaggio



SUT economica estesa ai settori energetici

B- Estrattivo

1. Coal extraction
2. Oil extraction
3. Natural Gas extraction
4. Ferrous and Nferrous extraction

D- Elettricità, gas , vapore aria condizionata

1. Electricity generation (type)
2. Electricity transmission
3. Electricity distribution
4. Gas steam and air conditioning

49 – Trasporti terrestri

1. Road transport
2. Railway transmission
3. Pipelines

Struttura BE

1. **Disponibilità di prodotti primari** da:
 - Produzione/estrazione
 - Importazione netta**Disponibilità di prodotti secondari** da
 - Importazioni nette
2. **Transformazione** attraverso impianti:
 - Input di prodotti primari
 - Output di prodotti secondari
3. **Settore Energetico** utilizzi propri
4. **Utilizzo Finale:**
 - Non energetico

 - Residenziale
 - Produttivo
 - Trasporto

BE: identità principali

Per ogni prodotto energetico

$$\text{Disponibilità Netta} + \text{Trasf. Output} = \text{Input Trasf} + \text{Distr. Perdite} + \text{Energy sector own Uses} + \text{Utilizzi finali (incl nonEnergy)}$$

Per ogni Centrale/Impianto

$$\text{Output} = \text{Input} - \text{Dispersioni}$$

Energy SUT

Passare da una rappresentazione monodimensionale (T-accounts), ossia BE, ad una matriciale (SUT)

- Similarità con la SUT economica:

Prodotti – Prodotti energetici

Sectori – Tipologia di impianti di trasformazione/elaborazione

Domanda Finale – Consumi finali dei prodotti per settori e/o destinazione

...quindi sarà possibile definire e stimare una USE energy matrix e una SUPPLY energy matrix

BE: Tipi di centrali ed impianti che entrano nella SUT Energia

Conventional Thermal Power Stations

1 - Electricity Producer Conventional Thermal Power Stations

2 - CHP Producer Conventional Thermal Power Stations

HydroElectric Power stations

Nuclear power stations

Coke - ovens

Blast - furnaces

Gas works

Refineries

Patent Fuel Plants

BKB / PB Plants

Charcoal production plants

District Heating Plants

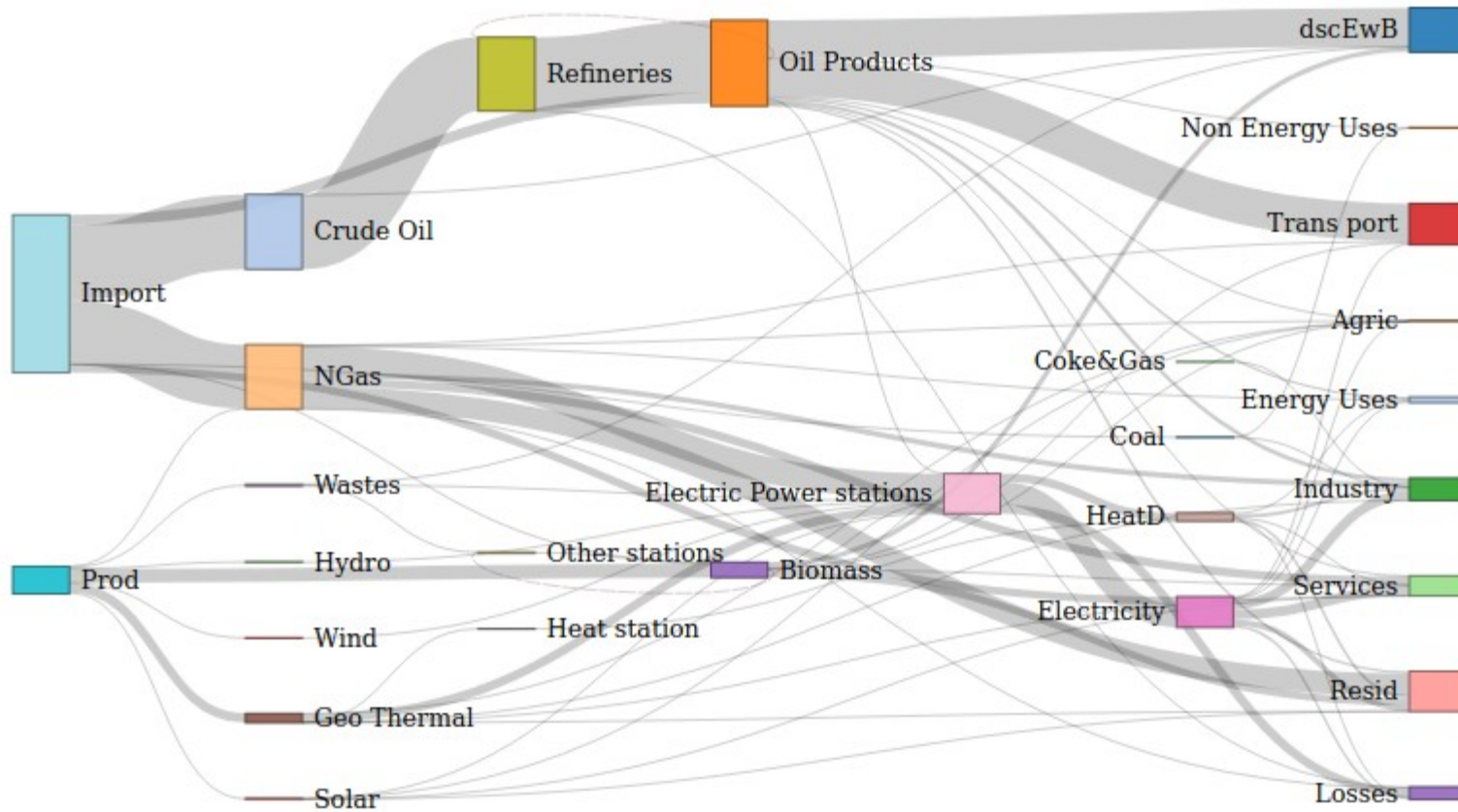
Other Renewables Power stations

Energy SUT aggregata: Toscana 2015

		Energy Products													Transformation Sectors					Other	Energy	Non Energy	Final uses					Losses			
		Coal	Crude Oil	Oil Products	NGas	Coke&Gas	Hydro	Wind	Solar	OtherBio	Wastes	Geo Thermal	HeatD	Electricity	Electric Power stations	Heat station	Cokery	Refineries	Other stations	Export/Bunkers				Agriculture	Industry	Services	Transport	Residential			
Energy Products	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.9	8.5	0.0	0.0	9.6	0.0	0.0	0.0	0.0	0.0		
	Crude Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4410.1	0.0	67.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	Oil Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.2	0.0	2281.3	133.4	27.1	53.2	221.6	36.5	1033.5	1351.1	0.0	0.0		
	NGas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1580.6	0.0	0.0	0.0	0.0	0.0	24.1	0.0	1.8	321.0	505.9	21.0	1381.0	15.7	0.0		
	Coke&Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0		
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	2.4	0.0	8.9	0.0	0.0		
	OtherBio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.7	0.0	0.0	0.0	0.0	2.5	300.0	0.0	2.7	0.0	5.1	70.6	441.2	0.0	0.0		
	Wastes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	67.0	0.0	0.0	0.0	22.8	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	Geo Thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	531.8	3.7	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.2	7.6	0.0	0.1	0.0	0.0		
	HeatD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	103.7	0.0	0.0	195.7	38.3	0.0	157.3	3.4	0.0		
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.1	0.0	0.0	25.1	587.5	604.0	73.7	339.3	134.2	0.0		
Transformation Sectors	Electric Power stations	485.5												1367.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	545.3	
	Heat station	13.5												0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.8	
	Cokery	0.0												0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	Refineries	4348.5												0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.8		
	Other stations	70.9												0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-45.6		
Production		0.9												47.7	19.1	88.1	821.5	112.3	546.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Import		13.2	4477.5	634.5	3826.3	0.0	0.0	0.0	0.0	0.0	23.6	0.0	0.0	477.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

Dalla SUT al modello.....

Flussi da SUT energia: Tuscany 2015



Energy SUT Toscana 2015: parametri

		Energy Products													Transformation Sectors					Other	Energy	Non Energy	Final uses					Losses			
		Coal	Crude Oil	Oil Products	NGas	Coke&Gas	Hydro	Wind	Solar	OtherBio	Wastes	Geo Thermal	HeatD	Electricity	Electric Power stations	Heat station	Cokery	Refineries	Other stations	Export/Importers				Agriculture	Industry	Services	Transport	Residential	Losses		
Energy Products	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0018	0.0000	0.2385	0.0000	0.0072	0.0000	0.0000	0.0000	0.0000	0.0000		
	Crude Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0000	0.0000	0.0000	1.0000	0.0000	0.0255	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
	Oil Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0019	0.0000	0.0000	0.0000	0.0000	0.8613	0.3896	0.7615	0.6156	0.1659	0.0304	0.8622	0.3673	0.0000			
	NGas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6590	0.0000	0.0000	0.0000	0.0000	0.0000	0.0704	0.0000	0.0210	0.2403	0.4216	0.0175	0.3754	0.1025			
	Coke&Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000			
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0199	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0079	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0317	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0020	0.0000	0.0024	0.0000			
	OtherBio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0299	0.0000	0.0000	0.0000	0.1002	0.1133	0.0000	0.0000	0.0310	0.0000	0.0043	0.0589	0.1199	0.0000			
	Wastes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0279	0.0000	0.0000	0.0000	0.8998	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
	Geo Thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2217	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0405	0.0001	0.0064	0.0000	0.0000	0.0000			
	HeatD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3031	0.0000	0.0000	0.1465	0.0319	0.0000	0.0428	0.0225			
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2369	0.0000	0.2905	0.4398	0.5034	0.0615	0.0922	0.8750				
Transformation Sectors	Electric Power stations														0.2620	0.7380	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Heat station															1.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cokery	1.0000													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	Refineries														0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	Other stations	1.0													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Production		1.0000	1.0000	0.0000	0.0002	0.0000	1.0000	1.0000	1.0000	0.8968	1.0000	1.0000	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Import		1.0000	1.0000	0.1273	0.9998	0.0000	0.0000	0.0000	0.0000	0.0258	0.0000	0.0000	0.0000	0.2586	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Losses		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2274	2.6291	0.0000	-0.0140	1.8044	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

C_e = product share

B_e = product input share

H_e = Energy Uses product share

H_{ne} = Non Energy Uses product share

r = transf. Losses coeff

1-Energy model

Type : *product* \times *product*, *industry technology*

..è un modello che risolve per il fabbisogno di prodotti energetici
Attivato da **Final Uses esogeni**

$$q_e = \left[I + \widehat{r \cdot C_e} - (B_e \cdot C_e + H_{ne} + H_e) \right]^{-1} \cdot (z + X_e + f_e)$$

The diagram illustrates the breakdown of energy demand q_e into different categories:

- q_e is broken down into:
 - Primary
 - Secondary
 - Secondary derived
- q_e is also broken down into:
 - Imported
 - Produced/extracted

On the right side, the equation components are further detailed:

- z (labeled Δ invent, bunkers export) points to X_e (labeled Production, transport).
- X_e points to f_e (labeled Residential, Household transport).

reef biregional model

Modello economico

$$\mathbf{x} = \left[\mathbf{I} - \mathbf{T} \cdot \left(\widehat{\mathbf{D}} \cdot \widehat{\mathbf{B}} \right) \right]^{-1} \cdot \left[\widehat{\mathbf{D}} \cdot (\mathbf{T} \cdot \mathbf{f} + \mathbf{ew}) \right]$$

$$\text{where } \mathbf{T} = \left(\mathbf{I} - \widehat{\mathbf{M}}_{\mathbf{w}} - \mathbf{M}_r \right) + \check{\mathbf{M}}_r$$

Linkages:

$$\mathbf{X}_e = \widehat{\Theta} \cdot \hat{\mathbf{x}}; \quad \mathbf{f}_e = \widehat{\Phi} \cdot \hat{\mathbf{f}}$$

Modello energetico

$$\mathbf{q}_e = \left[\mathbf{I} + \mathbf{r} \cdot \widehat{\mathbf{C}}_e - (\mathbf{B}_e \cdot \mathbf{C}_e + \mathbf{H}_{ne} + \mathbf{H}_e) \right]^{-1} \cdot (\mathbf{X}_e + \mathbf{f}_e)$$

Una simulazione: impatto export estero toscano 2015

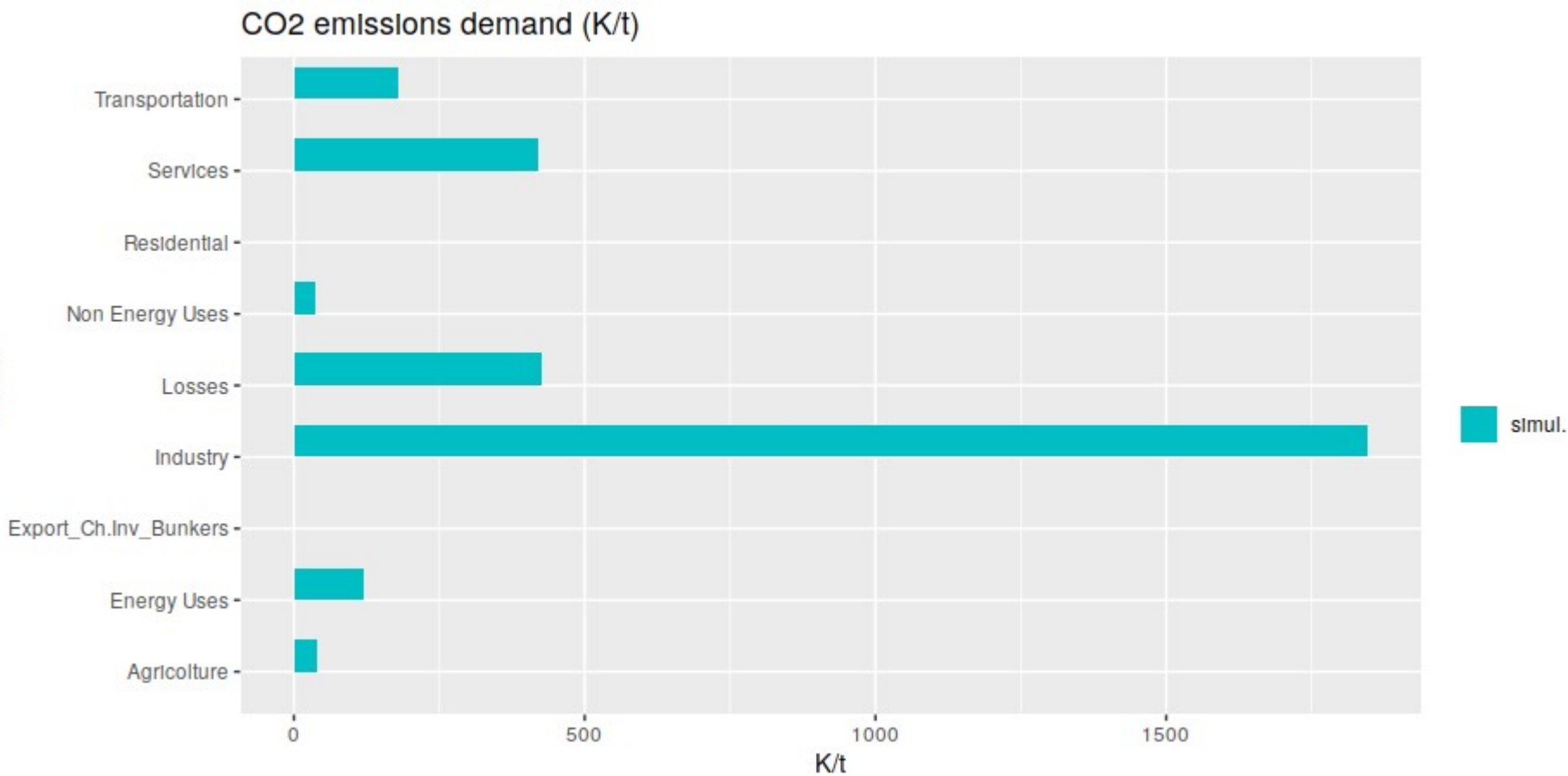
Export estero = 33451 (Meuro)

	Toscana	Resto Italia	ratio
PIL	18890	6160	3.067
Output	47080	16588	2.838
Co2 (kT)	3067	1794	1.710

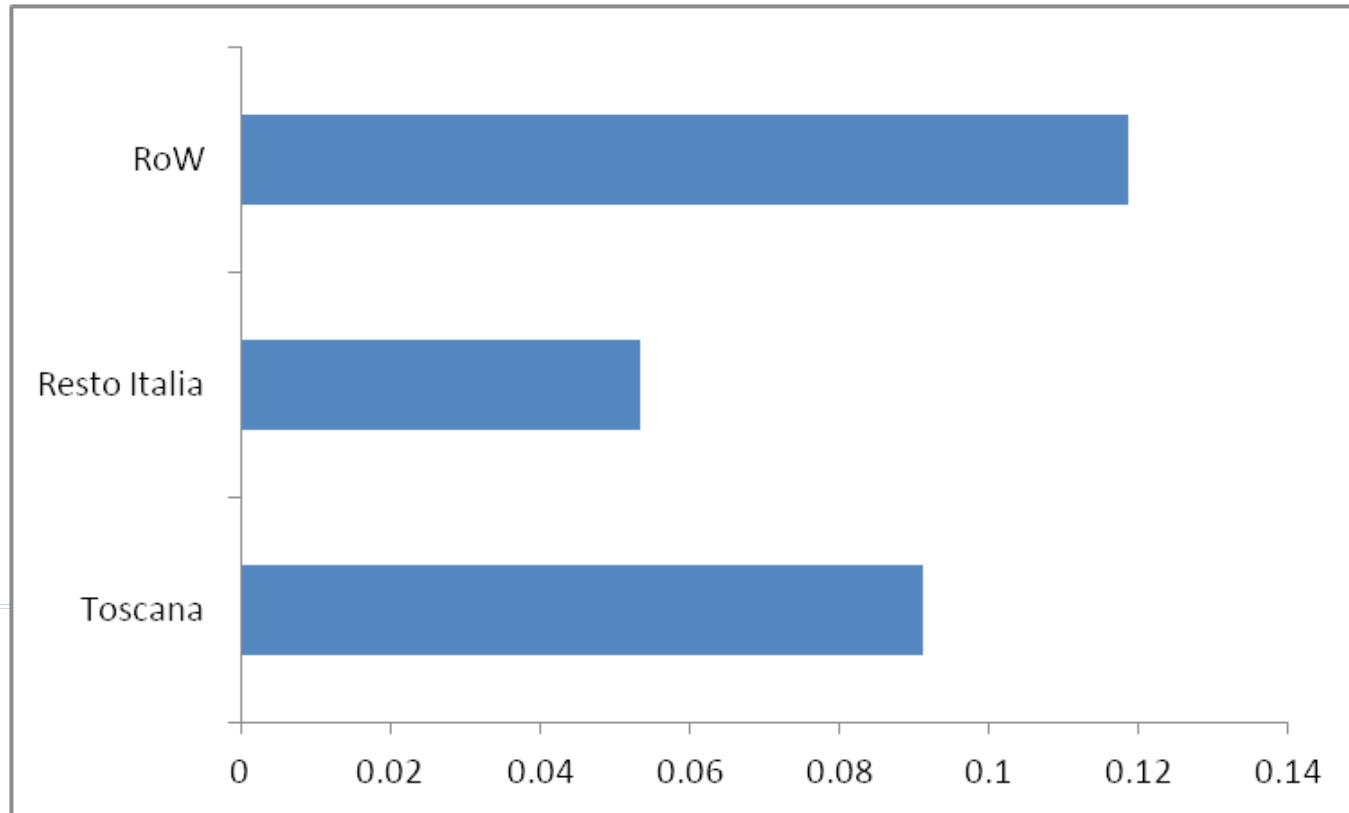
Impatto export estero Toscana (II): fabbisogno prodotti energetici

	Totale	Primario	Secondario	Secondario derivato	Importazioni
Coal	0.1	0	0.1	0	7.8
CrudeOil	2530.1	2462.7	67.5	0	2530.1
OilProducts	2508.9	1.1	2507.8	0	115
NGas	618.4	354.6	263.8	0	614.4
CokeGas	-20.5	0	-20.5	0	0
Hydro	10.9	10.9	0	0	0
Wind	4.3	4.3	0	0	0
Solar	17.4	17.3	0	0	0
Biomass	318.7	16.7	302.1	0	0
Wastes	20.2	20.2	0	0	0
GeoThermal	122.7	122	0.7	0	0
HeatD	109.6	0	0	109.6	0
Electricity	420.4	0	0	420.4	108.7

Impatto export estero Toscana (II): CO2 per domanda



Impatto export estero Toscana (III): carbon footprint (1 Meuro export)



Piani futuri

Aggiornamento e miglioramento SUT:

- 1- Conti energetici regionali ISTAT come vincolo
- 2- Ulteriore disaggregazione SUT economica

Modello:

- 1- Chiusura rispetto ai prezzi (soprattutto LCOE) ossia attivazione del circuito energia-sistema economico

Applicazioni:

- 1- Calcolo GHG footprint
- 2- Utilizzo del modello per stimare impatto transizioni energetiche



IRPET Istituto Regionale
Programmazione
Economica
della Toscana