PROGRAMA PARAGUAYO PARA EL DESARROLLO DE LA CIENCIA Y TECNOLOGÍA

CONACYT

FP-UNA - CONSTRUYENDO EL FUTURO

Grupo de Investigación en Sistemas Energéticos

INTEGRATED MULTI-CRITERIA PLANNING MODEL OF THE USE OF HYDROELECTRICITY SURPLUS OF PARAGUAY BASED ON ANALYTIC NETWORK PROCESS (ANP)

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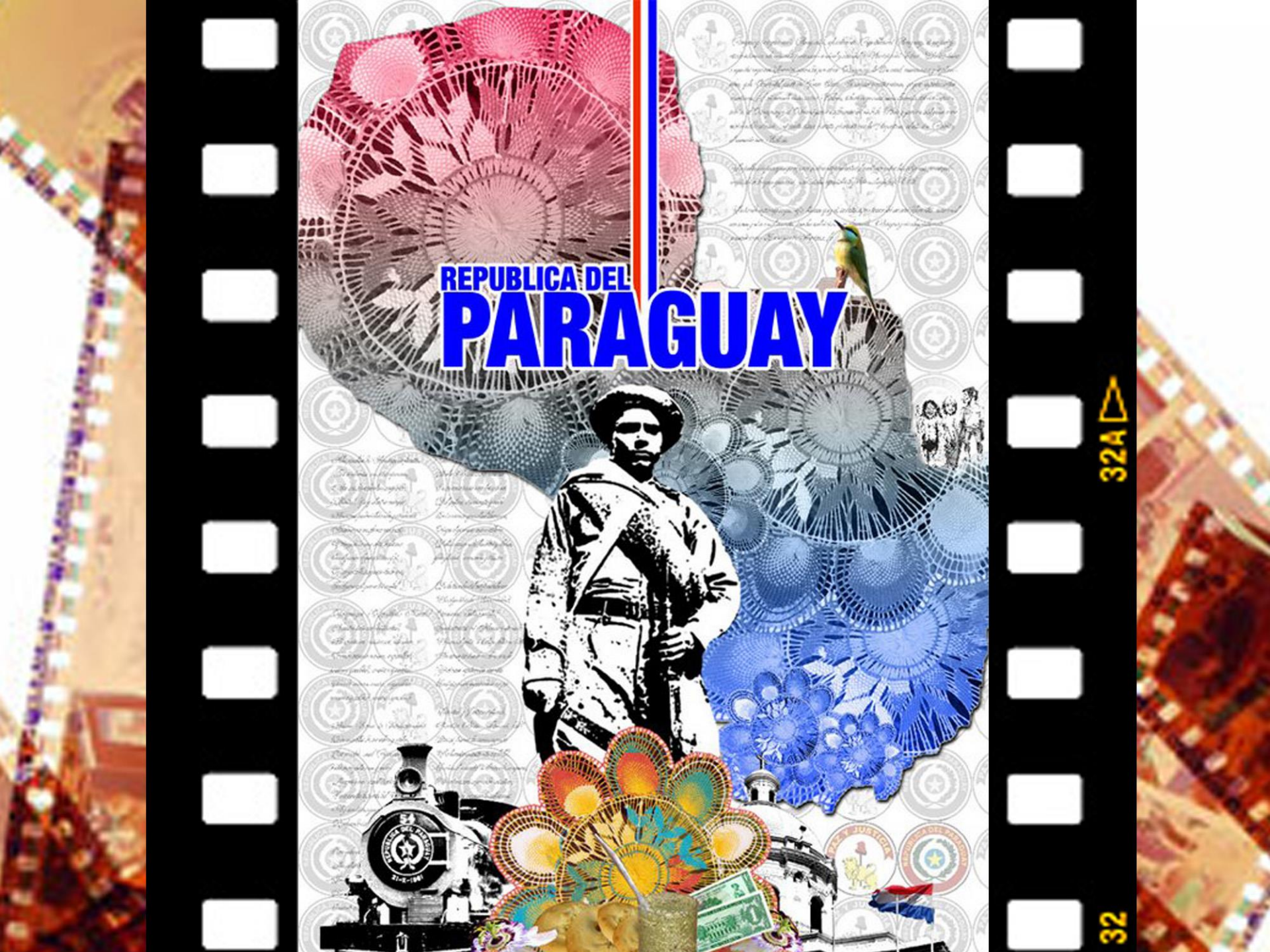
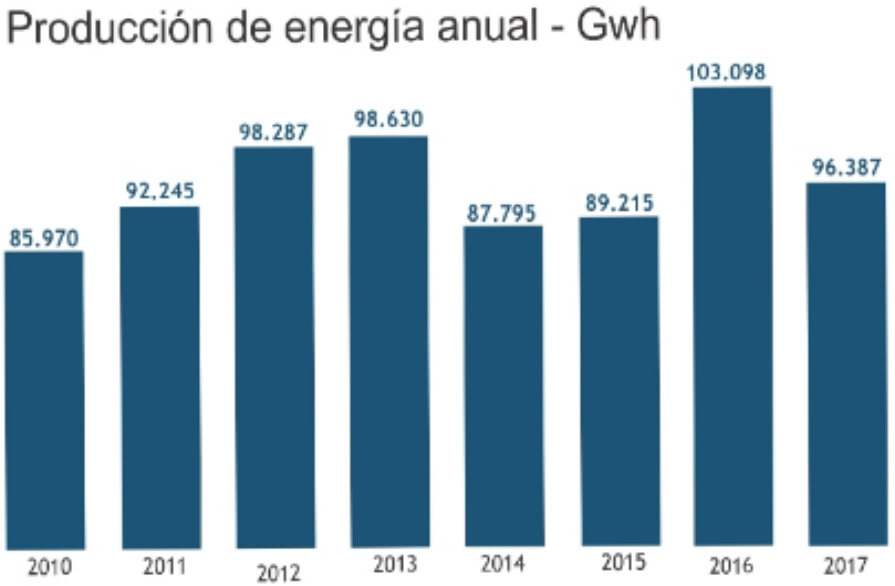
ISAHP 2018
HONG KONG, HK


REPUBLICA DEL
PARAGUAY
32A
32

ITAIPU BINATIONAL (PARAGUAY - BRASIL)

- Installed capacity: 14.000 MW
- 20 generating units
- World record for energy production



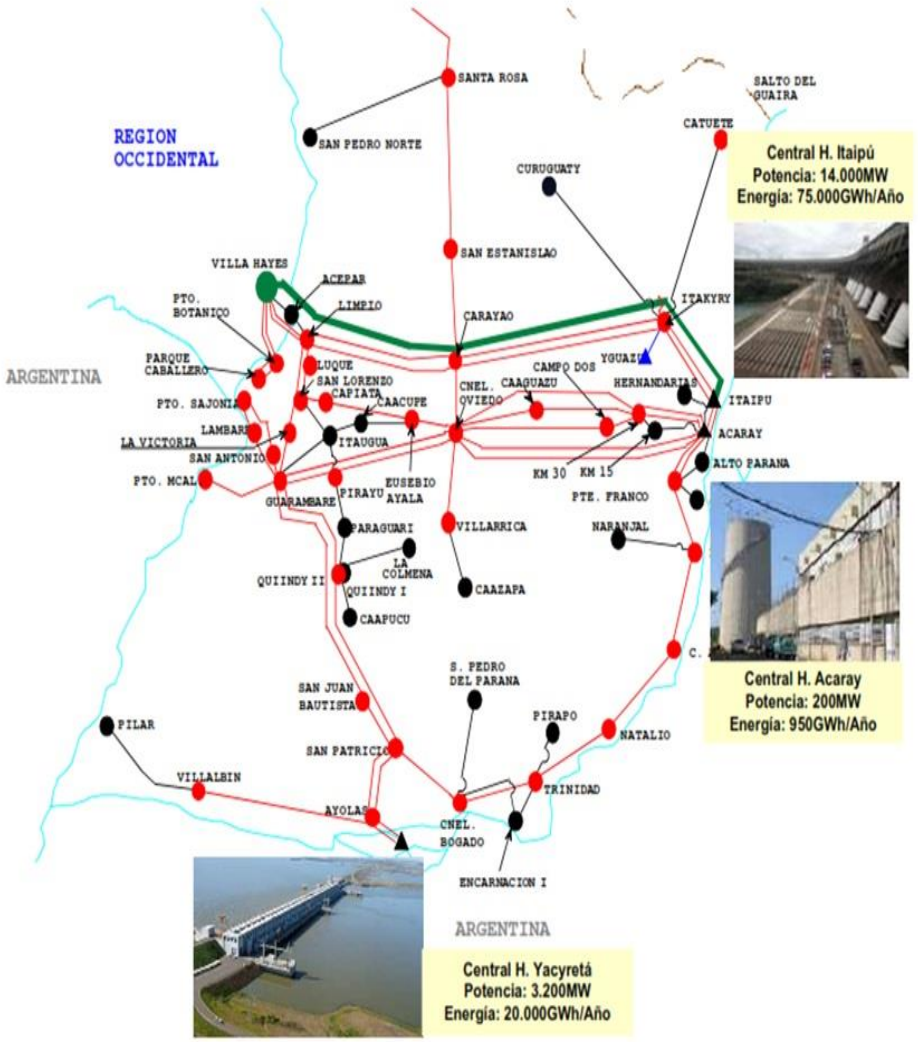
ITAIPU BINATIONAL (PARAGUAY - BRASIL)

YACYRETA (PARAGUAY - ARGENTINA)

- Installed capacity: 3.200 MW
- 20 generating units
- Annual energy production: 20.000 GWh

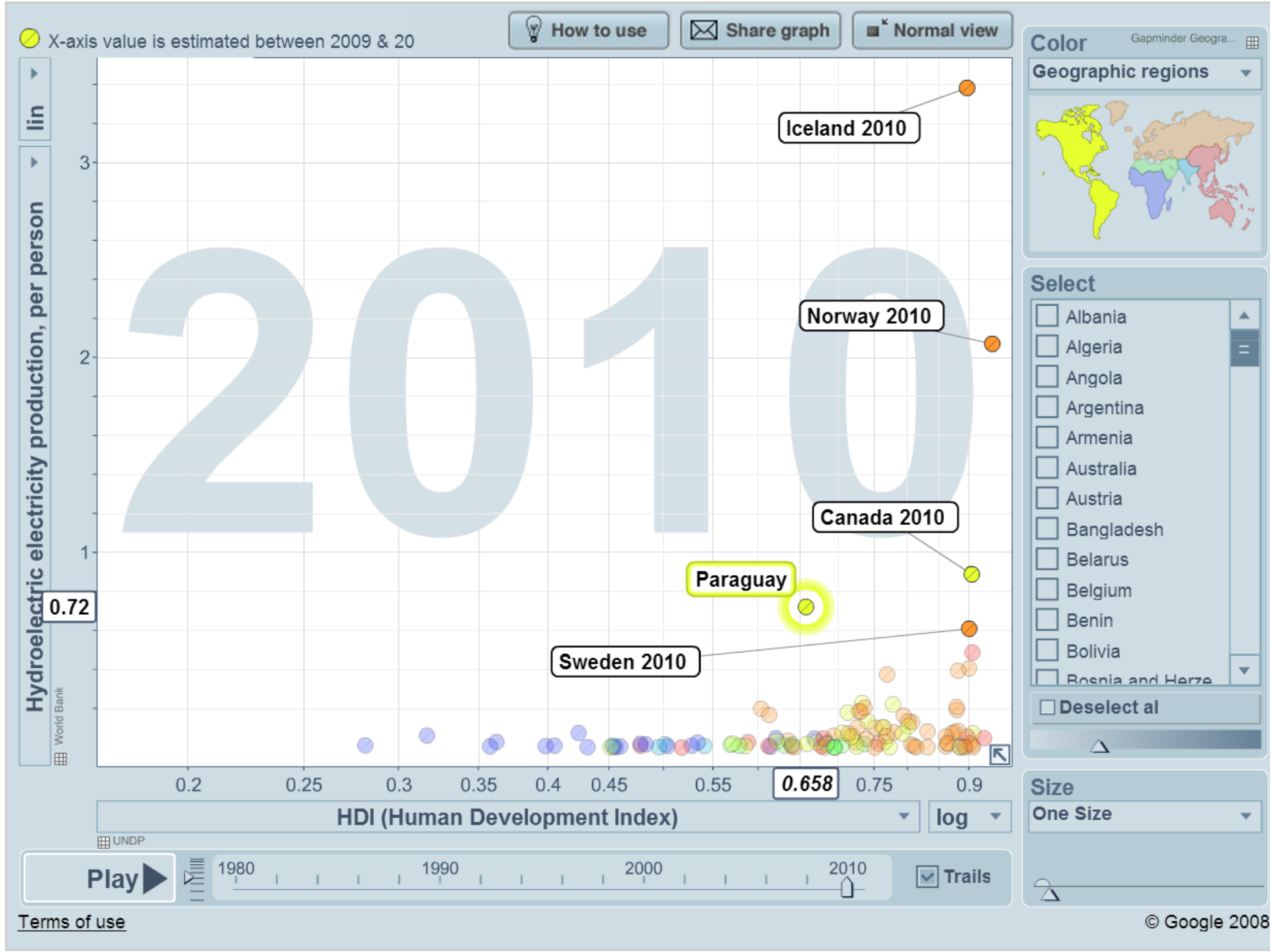
YACYRETA (PARAGUAY - ARGENTINA)

ITAIPU and YACYRETA



- Both power plants are on the Paraná River

- The Paraguayan planning will try to connect them through lines of 500 kilovolts, forming a kind of triangle


X-axis value is estimated between 2009 & 20
How to use
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lin
Hydroelectric electricity production, per person
2010
Iceland 2010
Norway 2010
Canada 2010
Paraguay
Sweden 2010
0.72
World Bank
3
2
1
0.2
0.25
0.3
0.35
0.4
0.45
0.55
0.658
0.75
0.9
HDI (Human Development Index)
log
UNDP
Select
Albania
Algeria
Angola
Argentina
Armenia
Australia
Austria
Bangladesh
Belarus
Belgium
Benin
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1980
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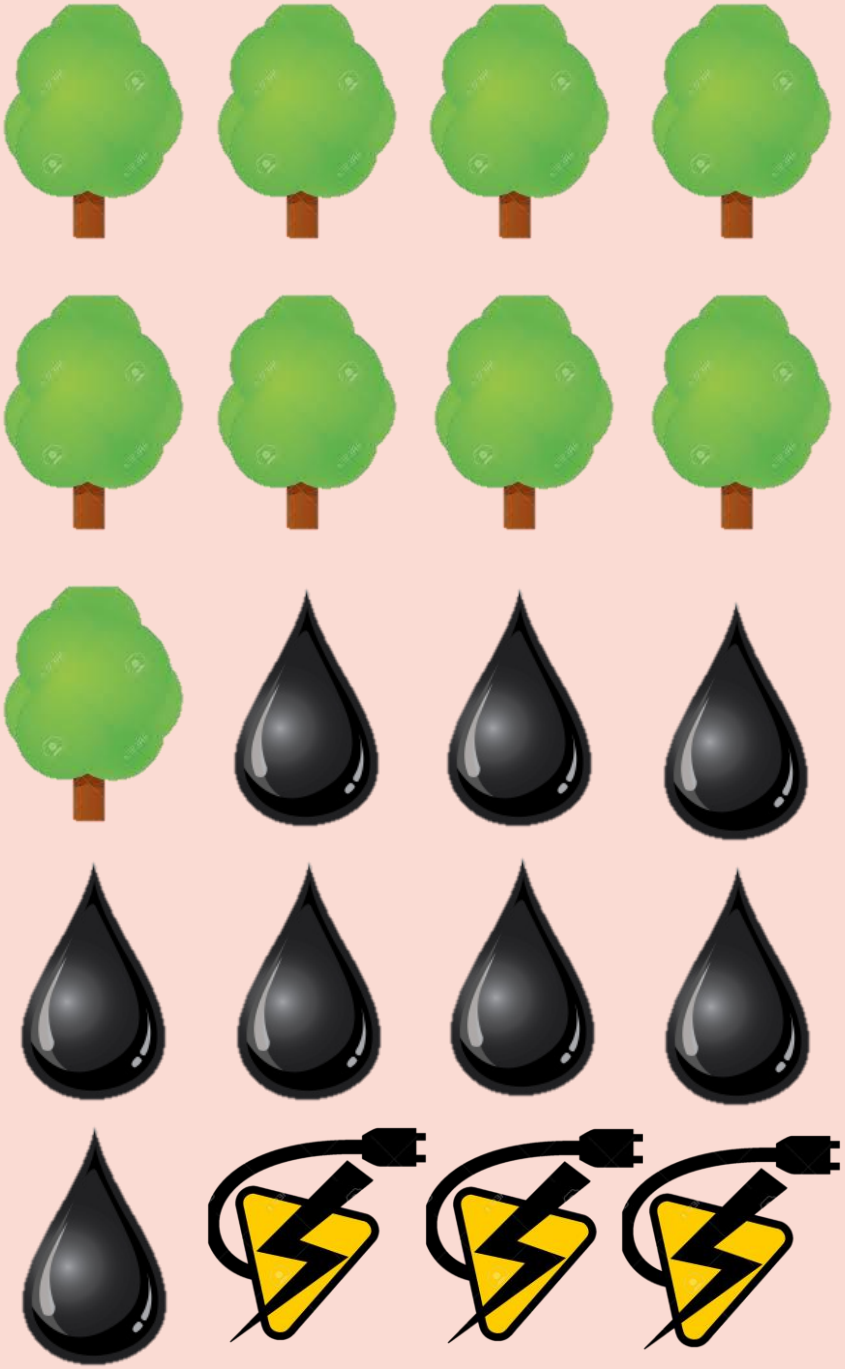
ENERGY MIX



45%
BIOMASS

38%
OIL FUELS

17%
ELECTRICITY

The Paraguayan Paradox

4th

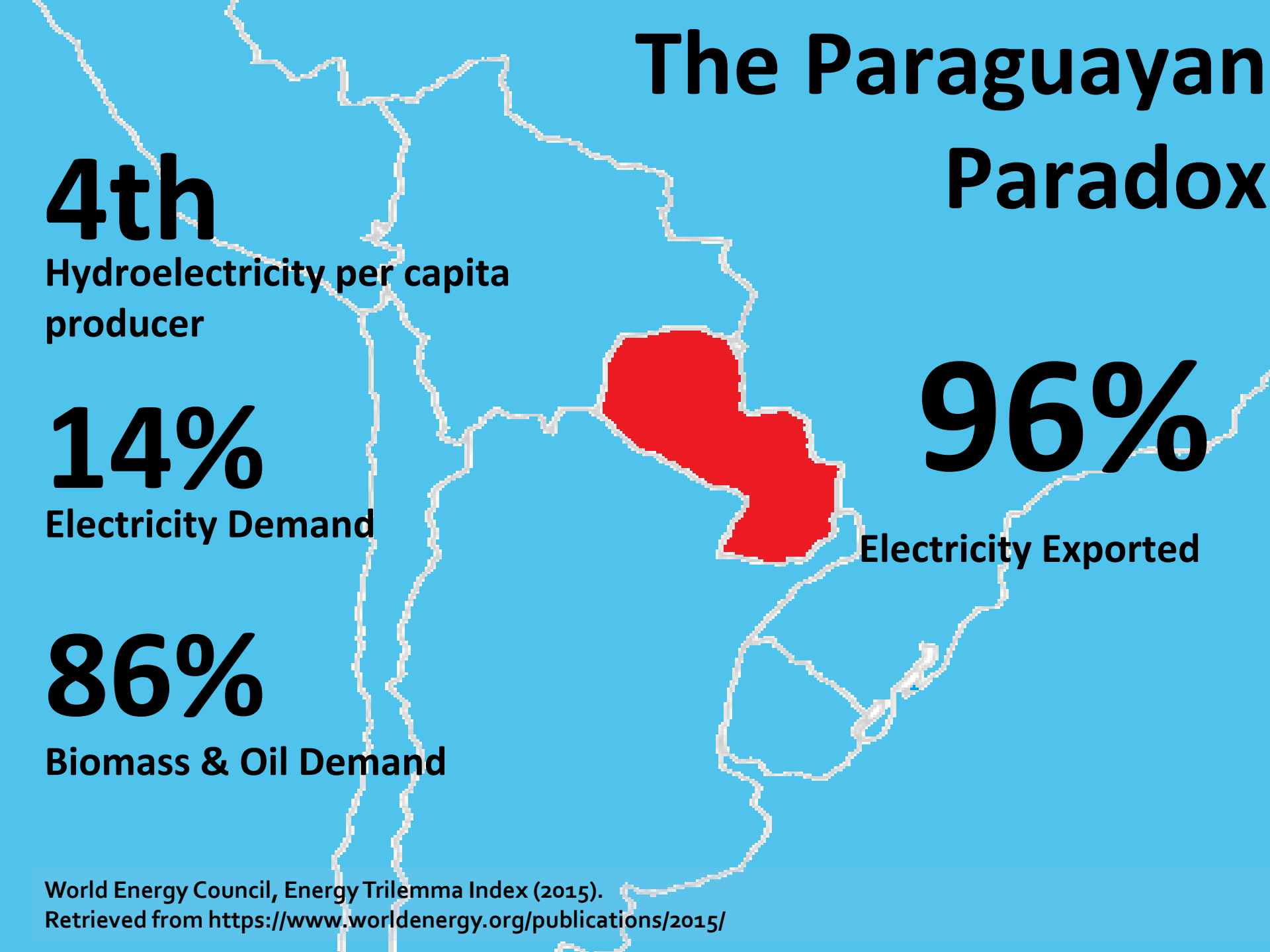
Hydroelectricity per capita producer

14%

Electricity Demand

86%

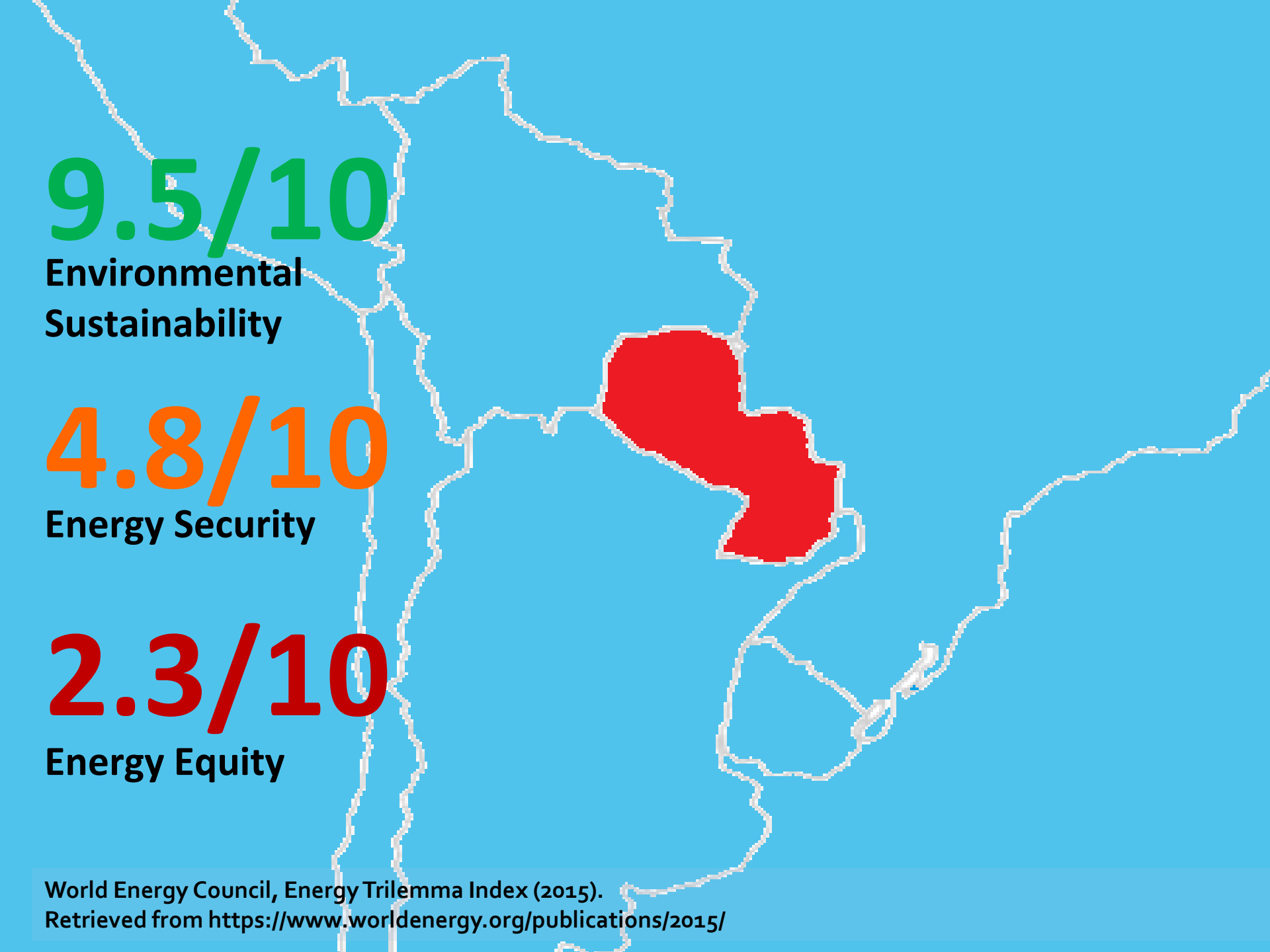
Biomass & Oil Demand



96%

Electricity Exported

World Energy Council, Energy Trilemma Index (2015).
Retrieved from https://www.worldenergy.org/publications/2015/



World Energy Council, Energy Trilemma Index (2015).
Retrieved from https://www.worldenergy.org/publications/2015/

Overall Objective

Propose a model based on the Analytical Network Process (ANP) to develop a decision-making tool in relation to the best use of Paraguay's hydroelectric surplus within the framework of a sustainable policy for achieve a social welfare and development.

Purpose of the Project

ANP

Energy Surplus

Criteria

ENERGY POLICY

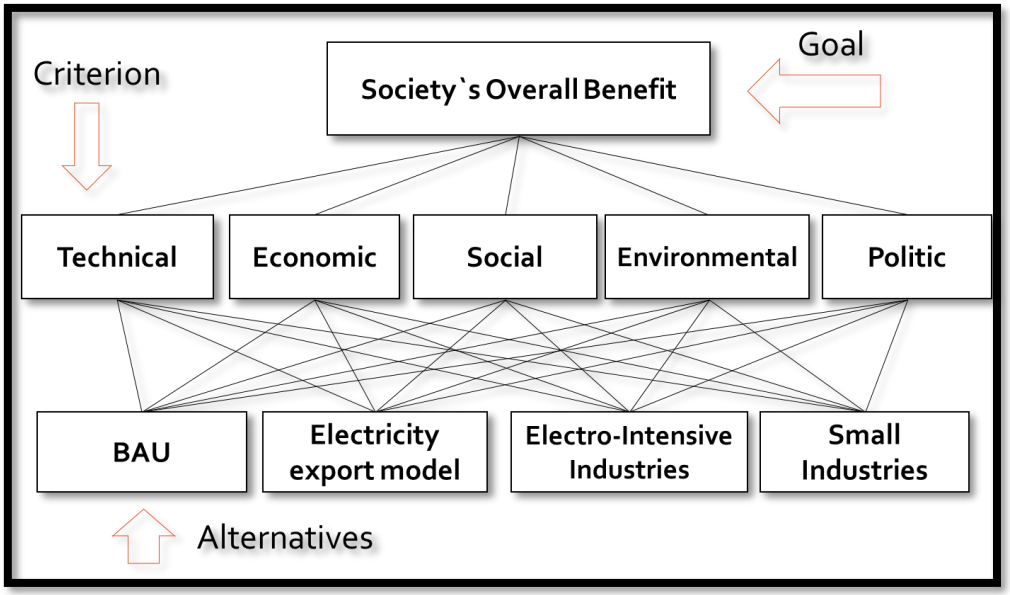
Environmental **Economic** **Social** **Technical** **Politic** **Energy Consumption**

Purpose of the Project Alternatives

ALT 1- A business as usual (BAU) scenario
ALT 2- A scenario of high hydropower exportation level
ALT 3- A scenario of high penetration level of electro-intensive industry
ALT 4- A scenario of high development of small industry

Methodology

Hierarchy of the Paraguayan Energy decision

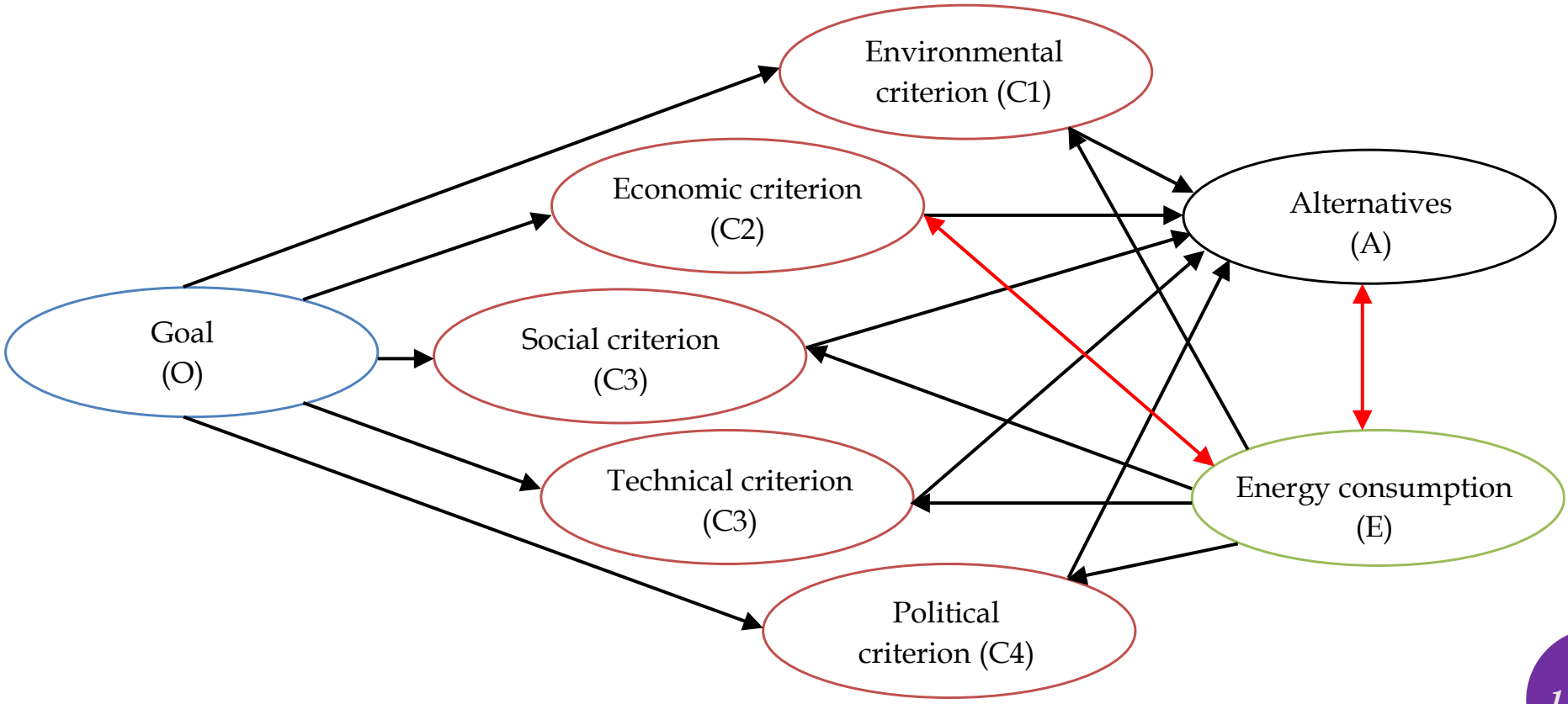


Alternatives	A1	A2	A3	A4
Priorities	0.241591	0.199644	0.271204	**0.287562**

A4 – A scenario of high development of small industry

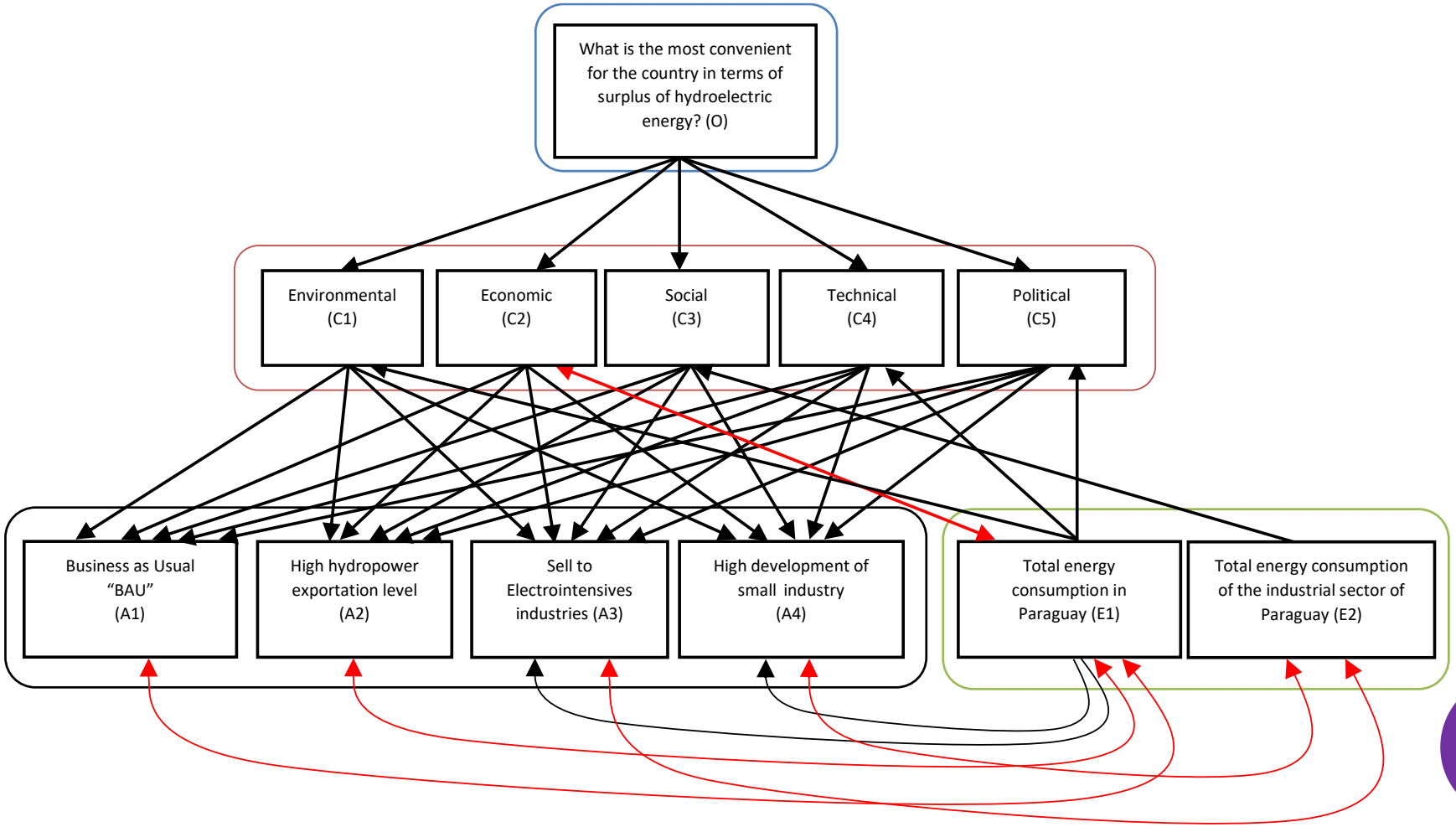
Methodology

Network structure of the relationship among clusters



Methodology

Network structure of ANP Model



Study Case
Elements of the Model

Clusters	Elements
C1 - Environmental Criterion	c1 - CO_2 Emissions
C2 - Economic Criterion	c2 - Impact on GDP
C3 - Social Criterion	c3 - Generated jobs
C4 - Technical Criterion	c4 - Expected Cost of Energy Not Supplied
C5 - Political Criterion	c5 - Implementation feasibility
E - Energy Consumption	E1 - Total energy consumption in Paraguay
	E2 - Total energy consumption of the industrial sector of Paraguay
A - Alternatives	A1 - Business as Usual "BAU": Paraguay remains ceding its electricity surplus to Brazil
	A2 - High hydropower exportation level: Electricity is sold in the Brazilian wholesale power market at market prices of around 50USD/MWh
	A3 - High electro-intensive industry penetration level: a factory resembling Aluminum Smelter RTA of 1100 MW is installed in the year 2017
	A4 - High development of small industry: Many small industries are installed. Industrial clusters of 180 MW are established beginning in 2017 and reach up an accumulated demand of 1100 MW.
O - Goal	o1 - What is the most convenient for the country in terms of surplus hydroelectric energy?

Study Case
Cluster Preferences

ANP Model Cluster Matrix								
	C1	***C2***	***C3***	***C4***	***C5***	***E***	***A***	***O***
C1	0	0	0	0	0	0,129	0	0,2
C2	0	0	0	0	0	0,162	0	0,2
C3	0	0	0	0	0	0,142	0	0,2
C4	0	0	0	0	0	0,147	0	0,2
C5	0	0	0	0	0	0,135	0	0,2
E	0	0,25	0	0	0	0	1	0
A	1	0,75	1	1	1	0,285	0	0
O	0	0	0	0	0	0	0	0

Study Case

Non-weighted Supermatrix

Non-weighted supermatrix of the ANP model

		C1	C2	C3	C4	C5	E		A				O
		c1	c2	c3	c4	c5	E1	E2	A1	A2	A3	A4	o1
C1	c1	0	0	0	0	0	1	0	0	0	0	0	1
C2	c2	0	0	0	0	0	1	0	0	0	0	0	1
C3	c3	0	0	0	0	0	0	1	0	0	0	0	1
C4	c4	0	0	0	0	0	1	0	0	0	0	0	1
C5	c5	0	0	0	0	0	1	0	0	0	0	0	1
E	E1	0	1	0	0	0	0	0	1	1	0	0	0
	E2	0	0	0	0	0	0	0	0	0	1	1	0
A	A1	0,350913	0,1205	0,052076	0,24969	0,434775	0,14088	0	0	0	0	0	0
	A2	0,350913	0,190632	0,052076	0,222594	0,182003	0,14088	0	0	0	0	0	0
	A3	0,18906	0,270707	0,191835	0,418093	0,286323	0,262833	0,25	0	0	0	0	0
	A4	0,109114	0,418461	0,704013	0,109623	0,096899	0,455408	0,75	0	0	0	0	0
O	o1	0	0	0	0	0	0	0	0	0	0	0	0

Study Case

Weighted Supermatrix

Weighted Supermatrix of the ANP model

		C1	C2	C3	C4	C5	E		A				O
		c1	c2	c3	c4	c5	E1	E2	A1	A2	A3	A4	o1
C1	c1	0	0	0	0	0	0,150235	0	0	0	0	0	0,2
C2	c2	0	0	0	0	0	0,188501	0	0	0	0	0	0,2
C3	c3	0	0	0	0	0	0,000000	0,331640	0	0	0	0	0,2
C4	c4	0	0	0	0	0	0,170836	0	0	0	0	0	0,2
C5	c5	0	0	0	0	0	0,157842		0	0	0	0	0,2
E	E1	0	0,250000	0	0	0	0	0	1	1	0	0	0
	E2	0	0	0	0	0	0	0	0	0	1	1	0
A	A1	0,350913	0,090375	0,052076	0,249690	0,434775	0,046855	0	0	0	0	0	0
	A2	0,350913	0,142974	0,052076	0,222594	0,182003	0,046855	0	0	0	0	0	0
	A3	0,189060	0,203030	0,191835	0,418093	0,286323	0,087414	0,167090	0	0	0	0	0
	A4	0,109114	0,313846	0,704013	0,109623	0,096899	0,151462	0,501270	0	0	0	0	0
O	o1	0	0	0	0	0	0	0	0	0	0	0	0

Study Case
Limit Supermatrix

Limit Supermatrix of the ANP model													
		C1	***C2***	***C3***	***C4***	***C5***	***E***		***A***				***O***
		c1	***c2***	***c3***	***c4***	***c5***	***E1***	***E2***	***A1***	***A2***	***A3***	***A4***	***o1***
C1	***c1***	0,0039	0,0039	0,0039	0,0039	0,0039	0,0039	0,0039	0,0039	0,0039	0,0039	0,0039	0,0039
C2	***c2***	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049
C3	***c3***	0,1327	0,1327	0,1327	0,1327	0,1327	0,1327	0,1327	0,1327	0,1327	0,1327	0,1327	0,1327
C4	***c4***	0,0044	0,0044	0,0044	0,0044	0,0044	0,0044	0,0044	0,0044	0,0044	0,0044	0,0044	0,0044
C5	***c5***	0,0041	0,0041	0,0041	0,0041	0,0041	0,0041	0,0041	0,0041	0,0041	0,0041	0,0041	0,0041
E	***E1***	0,0260	0,0260	0,0260	0,0260	0,0260	0,0260	0,0260	0,0260	0,0260	0,0260	0,0260	0,0260
	E2	0,4002	0,4002	0,4001	0,4002	0,4002	0,4002	0,4001	0,4002	0,4002	0,4001	0,4001	0,4002
A	***A1***	**0,0128**	0,0128	0,0128	0,0128	0,0128	0,0128	0,0128	0,0128	0,0128	0,0128	0,0128	0,0128
	A2	**0,0119**	0,0119	0,0119	0,0119	0,0119	0,0119	0,0119	0,0119	0,0119	0,0119	0,0119	0,0119
	A3	**0,0994**	0,0994	0,0994	0,0994	0,0994	0,0994	0,0994	0,0994	0,0994	0,0994	0,0994	0,0994
	A4	**0,3008**	0,3009	0,3008	0,3008	0,3008	0,3008	0,3008	0,3008	0,3008	0,3008	0,3008	0,3008
O	***o1***	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

Study Case
General Results

Clusters		Limit Supermatrix Results	Normalization	Priority (%)
(A) Policy Options	*(A1): Continue with normal course of operations.*	0,0131	0,0302	3,02%
	(A2): High hydropower export level.	0,0122	0,0281	2,81%
	(A3): High electro-intensive industry penetration level.	0,1015	0,2338	23,38%
	(A4): High development of small industry.	0,3072	0,7079	70,79%
TOTAL		**0,4249**	**0,4340**	**1**


Government Palace

Conclusions

- We have shown the usefulness of ANP to select the best alternative to promote the management of surplus hydropower in the country
- It was possible to show that this scientific tool combines quantitative and qualitative aspects when making a decision
- According to the case study considered, the best strategy for the country is developing its industrial sector through the use of electrical energy available

Thank you very much for the attention

Questions and suggestions

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