BIOFUEL SUSTAINABILITY ASSESSMENT

Tools and methods in a professional approach: a contribution from AISA

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- From 2004 Professional Association
- Members distributed all over Italy
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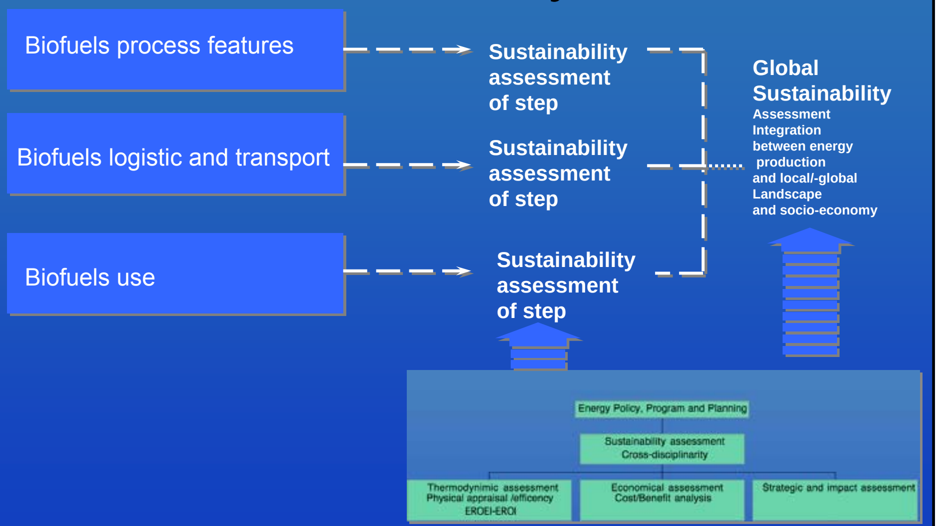
Biofuel cycle and impact assessment (1)

- Economic Return on Investment
- Thermodynamic assessment / energetic balance
- Impact assessment
- Strategic impact assessment (effects & impacts on society, landscape, cumulative impacts, sustainability)

Biofuel cycle and impact assessment (2)

- 1. Biofuel Production
- 2. Biofuel transport, logistic and distribution
- 3. Biofuel consumption
- 4. Integration between the production of energy and landscape
- 5. Biofuel in sustainability dynamics of the regional socio-economy

Biofuel life cycle



Methodological note 1

Sustainability

Definition:

$Q_E = Q_{E,nature} + Q_{E,anthropic}$ Q_E=environmental quality;

$Q_{E,anthropic} = Q_{E,\,society-health} + Q_{E,\,culture} + Q_{E,\,economy}$

In a weak sustainability framework:

$dQ_E/dt \geq 0$

In a strong sustainability framework:

$dQ_E/dt \geq 0$

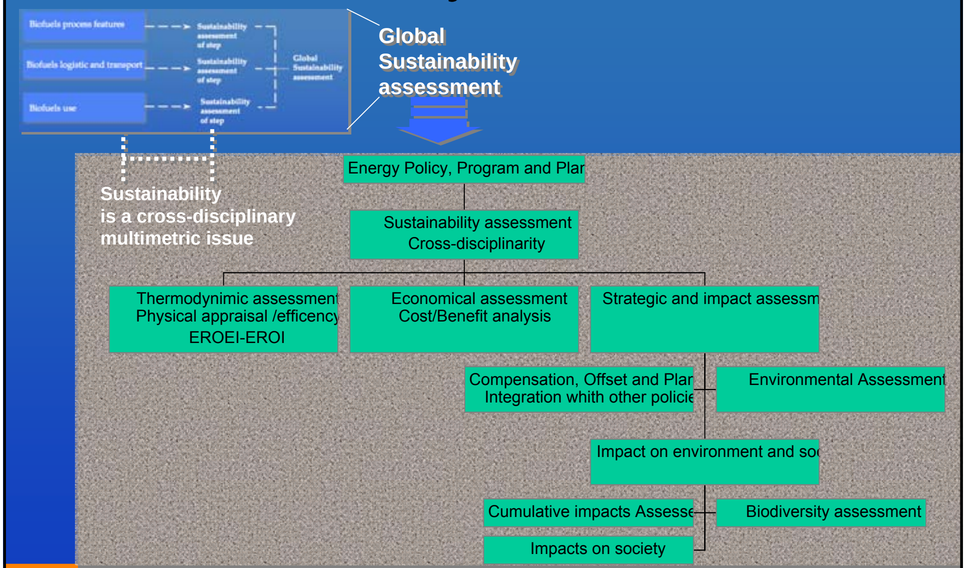
Sub condicio: $\partial Q_{E,nature}/\partial t \geq 0$;

$\partial Q_{E,\,culture}/\partial t \geq 0$; $\partial Q_{E,\,society-health}/\partial t \geq 0$

Operational hypothesis:

$Q_E = Q_{E,nature} + Q_{E,anthropic} \approx Q^*_{E,nature} + Q^*_{E,anthropic} + Q_{E,landscape} - I_{cumulative}$

Sustainability Assessment



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Biofuel Sustainability

- Building blocks sustainability assessment along the entire value chain for the production of second generation biofuel, power and heat (LCA approach) [VII FP]
- Clustering of mass production
- $E = E_a + E_t + E_{tr}$ Total Energy of the process (agriculture, transport, transformation)
- $C = C_a + C_t + C_{tr}$ Total Costs

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Energy - EROI (E_{out}/E_{in})

Physical/ dimension - Energy balance and computation

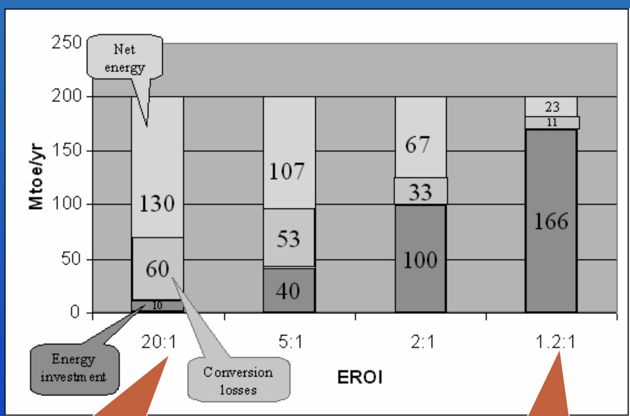
Costs: economic, environmental, social

Societal Dimension

Impacts: irreversibility, cumulative, social and health, off-sets (ecological footprint)

Environmental impact Dimension

EROI



Oil

Biofuel

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Process	EROEI Cleveland[2]	EROEI Elliott[3]	Hore-Lacy[4]
Fossil Fuels			
Oil		**50 – 100**	
- 1940	**100**		
- 1970	**23**		
- today	**8**		
Carbon		**2 - 7**	**7 – 17**
- 1950	**80**		
- 1970	**30**		
Natural Gas	**1 – 5**		**5 - 6**
Schist bitumen	**0,7 - 13,3**		
Nuclear			
Uranio 235	**5 – 100**	**5 – 100**	**10- 60**
Renewable			
Biomass		**3 – 5**	**5-27**
Hydroelectric	**11,2**	**50 – 250**	**50- 200**
wind		**5 – 80**	**20**
Geotermic	**1,9 – 13**		
solar thermal	**1,6 – 1,9**		
thermodynamics	**4,2**		
photovoltaic	**1,7 – 10**	**3 – 9**	**4 – 9**
Bio-Ethanol			
- Sugar cane	**0,8- 1,7**		
- Corn	**1,3**		
- Cornresidues	**0,7 – 1,8**		
Biomethanol	**2,6**		

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Resource side

Biofuel production		**Ethanol**	**Biodiesel**	**Methanol**
Oil equivalent demand per unit of biofuel	g/g	0.60	0.82	0.108
Fertilizers and pesticides demand per unit of biofuel	g/g	0.15	0.37	0.114
Material intensity, abiotic factor	g/g	7.45	13.97	n.a.
Material intensity, biotic factor	g/g	0.35	0.79	n.a.
Material intensity, water factor	g/g	4811.21	2852.61	n.a.
Soil erosion	g/g	8.78	19.74	n.a.
Labor demand per unit of biofuel	hrs/kg	0.02	0.04	0.01
Land demand per unit of biofuel	m^2/kg	5.10	11.48	12.6
Net energy yield	MJ/Ha	1.89E+04	4.88E+03	1.40E+03
Net energy return per hour of applied labor	MJ/hr	613.55	145.77	133.08
Economic cost per unit of biofuel	$/kg	0.50	0.61	n.a.

Source: Ulgiati S., Russi D., Raugei M., 2008. Biofuel Production in Italy and Europe: Benefits and Costs, in the Light of the Present European Union Biofuel Policy. Biofuels, Solar and Wind as Renewable Energy Systems Benefits and Risks. Edited by D.Pimentel , Springer Earth and Environmental Science, Dordrecht.ISBN 978-1-4020-8653-3 pp. 465-491

LAND USE CHANGE: RUSSI (2008) concludes that "the equivalent of about one-third of the Italian agricultural land would be needed." In Europe (Biomass Action Plan, Annex 11, 2006) 17 milions of hectars would be needed.

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Downstream impacts

Waste and releases		Ethanol	Biodiesel	Methanol
CO_2 released per unit of substrate	g/g	0.32	0.98	0.38
CO_2 released per unit of biofuel	g/g	2.02	3.21	1.54
Industrial wastewater released per unit of biofuel	g/g	9.08	n.a.	n.a.

Source: Ulgiati S., Russi D., Raugei M., 2008. Biofuel Production in Italy and Europe: Benefits and Costs, in the Light of the Present European Union Biofuel Policy. Biofuels, Solar and Wind as Renewable Energy Systems Benefits and Risks. Edited by D.Pimentel , Springer Earth and Environmental Science, Dordrecht. 2008. XI, 372 pp.ISBN 978-1-4020-8653-3 pp. 465-491

Green House Gas inventory

Crops/Wood for production and use of energy from biofuels
(CO_{2eq} emission) / (CO_2 absorption) ≈ 1,2÷1,8

Crops residual for production and use of energy from biofuels
(CO_{2eq} emission) / (CO_2 absorption) ≈ 1,0÷1,5

Waste or production and use of energy from biogas
(CO_{2eq} emission) / (CO_2 absorption) ≈ 0,8÷1,3

Ecological Footprint

Electricity Production by	Ecological Footprint (ha/yr per GWh)
Steam Power Plant by Coal	161
Coal Plant	198
Oil Plant	150
Natural gas Plant (turbogas)	94
Nuclear Plant	**From 150 to 200**
Wind farm	6
Photovoltaic	24
Biomass Wood	from 27 to 46
Hydroelectric	From 10 to 75

Sources
Chambers N., C. Simmons, M. Wackernagel, 2000. *Sharing Nature's Interest . Ecological Footprint as Indicator of sustanability*, Earthscan, London, 168 p.

Renewables 2050. A Report on the Potential of Renowables Energies in Peninsular Spain: Recursos Renovables Disponibles en España y Comparacion con la Demanda en 2050; in http://www.greenpeace.org/espana/footer/search?q=renovables+2050

Other known issues for producers

- Economic:
  - increasing in the import (and price) of food and feedstock
  - descreasing of alimentary sovereignty
  - Monocultures market dependendecy
- Social:
  - Energy revenues reduction
  - Rural development
- Environmental
  - heavy use of fertilizers, pesticides, and machinery.
  - reduction of wild and agricultural biodiversity
  - reduction of water availability and quality
  - increased use of genetically modified organisms (GMOs)

Strategic assessment

Look at the opportunity costs/benefits:

- production
- mass flow clustering
- output kind

Second generation biofuels, heat biofuel

Integration of energetic policies (strategic decision on optimal mix)

Cumulative impacts

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Strategic assessment of energy Production and consumption

Energy production of local and regional level (optimal or sub-optimal mix)

- Local energetic mix, LEp
- Regional energetic mix, REp

Strategic assessment of energy

Energy production of local and regional level

Local energetic mix, LEp

LEp = Local Energetic production

¿Optimal mix Ep in the *l* ***Lep*** strategies? Choice between the max (LEp_i)

$$LEp_1 = E_{11} + E_{12} + \ldots E_{1n}$$

(…)

$$LEp_l = E_{l1} + E_{l2} + \ldots E_{ln}$$

under the constraints C=C(P, W, L, E, Ec, BGC, C, H_2O, H, PS, Hh)

Regional energetic mix, REp

Ei= energy production from i source; P=pollution; W=waste; L=Landscape; E=Ecology; Ec= economy; BGC=Biogeochemical cycles; C=climate; H_2O=water consumption; H=household, PS=production sectors; Hh= Human health; EF=ecological footprint; B&G=biodiversity and Geodiversity

Strategic assessment of energy

Energy production of local and regional level

Local energetic mix, LEp

Regional energetic mix, REp

¿Optimal mix in the *m* **REp** strategies? Choice between the max (Rep_i)

$$\mathbf{REp_1} = \sum_j (LEp_{11} + LEp_{12} \ldots + LE_{1j}),$$

(…)

$$\mathbf{Rep_m} = \sum_j (LEp_{m1} + LEp_{m2} \ldots + LE_{mj}),$$

under the constraints S=S(C1,…Cj; EF, GhE, B&G)

Ei= energy production from i source; P=pollution; W=waste; L=Landscape; E=Ecology; Ec= economy; BGC=Biogeochemical cycles; C=climate; H_2O=water consumption; H=household, PS=production sectors; Hh= Human health; EF=ecological footprint; B&G=biodiversity and Geodiversity

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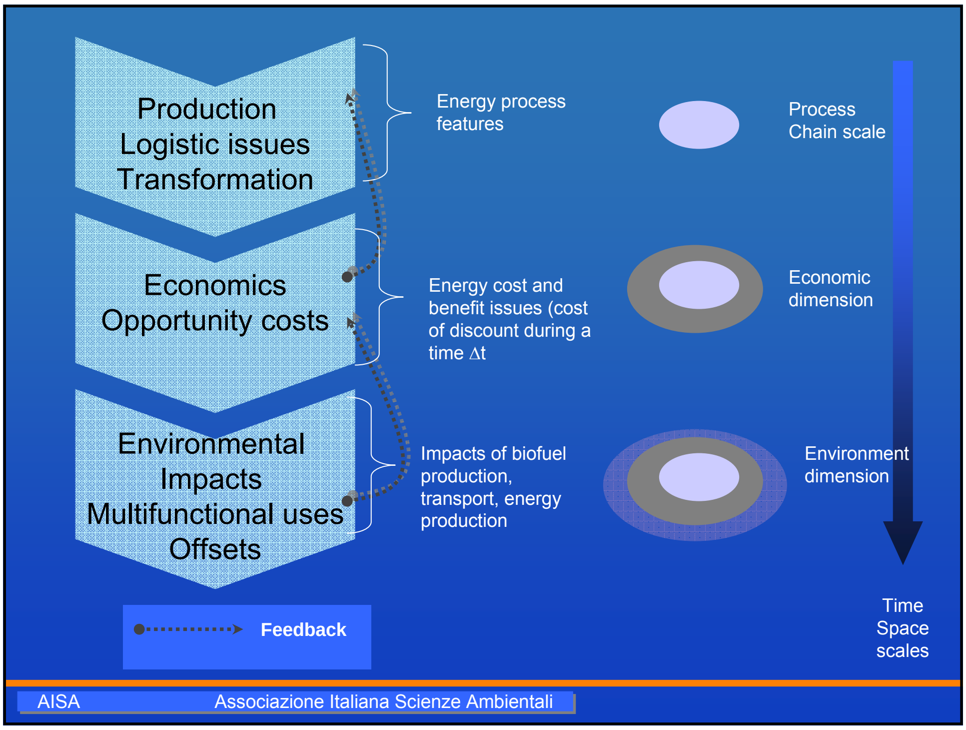

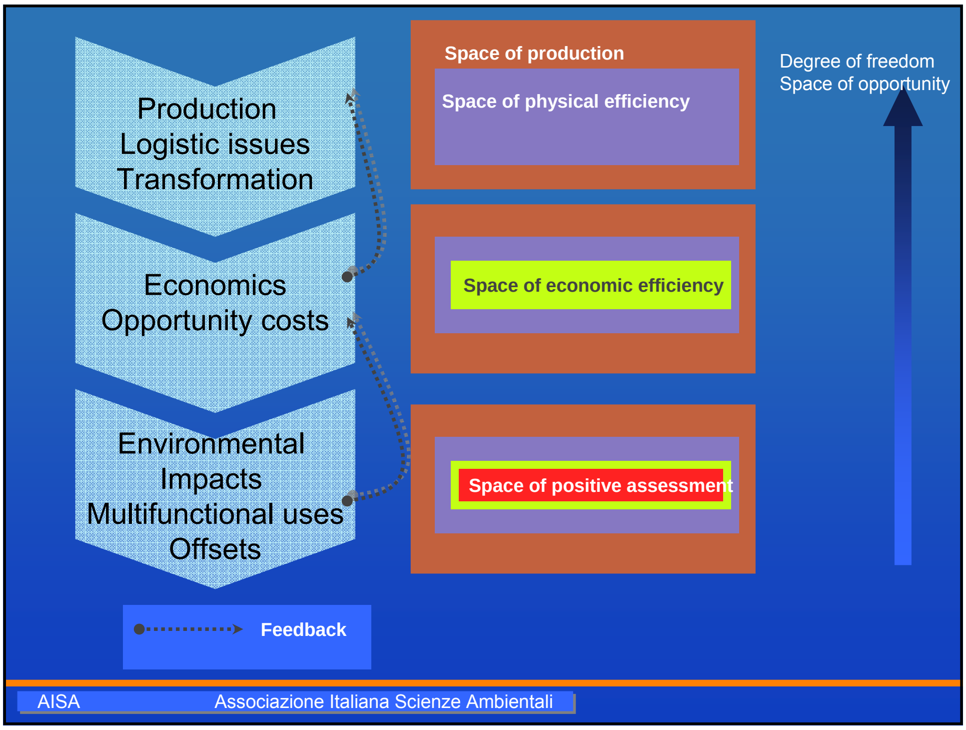

Methodological note 2

Cumulative impacts 1

- Cumulative impacts refer to progressive environmental degradation over time arising for a range of activities (Gilpin, 1995).
- Cumulative impact assessment takes in account persistent addition from one process or compounds impacts involving two or more processes.

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Methodological note 2

Cumulative impacts 2

- Cumulative impacts is the individuation of:

Severity - magnitude of impacts

Duration - time scale

$C= \sum_t (\sum_i (I)_i \quad + \quad \sum_j (I)_j)$; if addictive or

$C= \sum_t (\prod_i (I)_i \quad + \quad \prod_j (I)_j)$; if multiplicative

Project or process persistent additions

Compounding effects from Other projects / processes

Methodological note 2

Cumulative impacts 3

- Cumulative impacts is the individuation of:

Severity - magnitude of impacts: f(◦); g(◦); cumulative functions

Duration - time scale dt

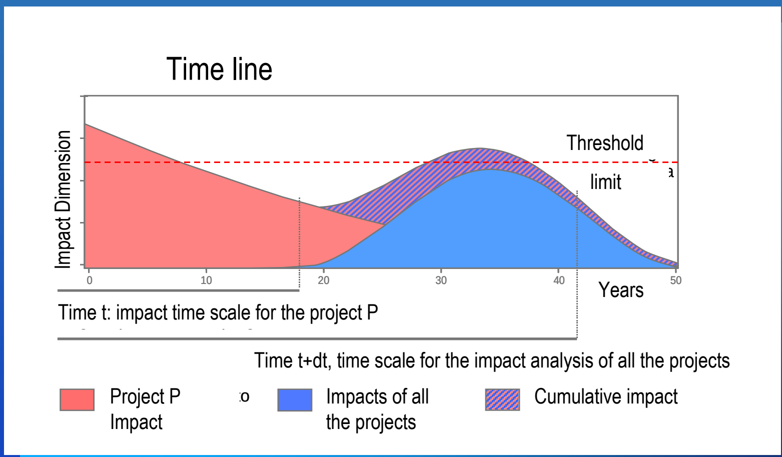
Extent - space dimension dx

$C= \int (\int f(I) \, dx \quad + \quad \int g(I) \, dx) \, dt$;

Project or process persistent additions over time and space

Compounding effects from Other projects / processes over time and space

Methodological note 2



Methodological note 3

Social Issues and impacts Multicriteria analysis

- World Bank. 1996. Guidelines for using social assessment to support public involvement in World Bank GEF projects. The World Bank, Washington, D.C.. 66 p.
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- Gamboa G., G. Munda, 2006. The Problem of windfarm location: A Social multi-criteria evaluation framework, Energy Policy, 35-3-1564-1583.