Emergy Evaluation of the Total Pollutant Load Management System in the Masan Bay Area in Korea

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Daeseok Kang, Pukyong National University
Jungho Nam, Korea Maritime Institute
Won Keun Chang, Korea Maritime Institute
Jongseong Ryu, Anyang University

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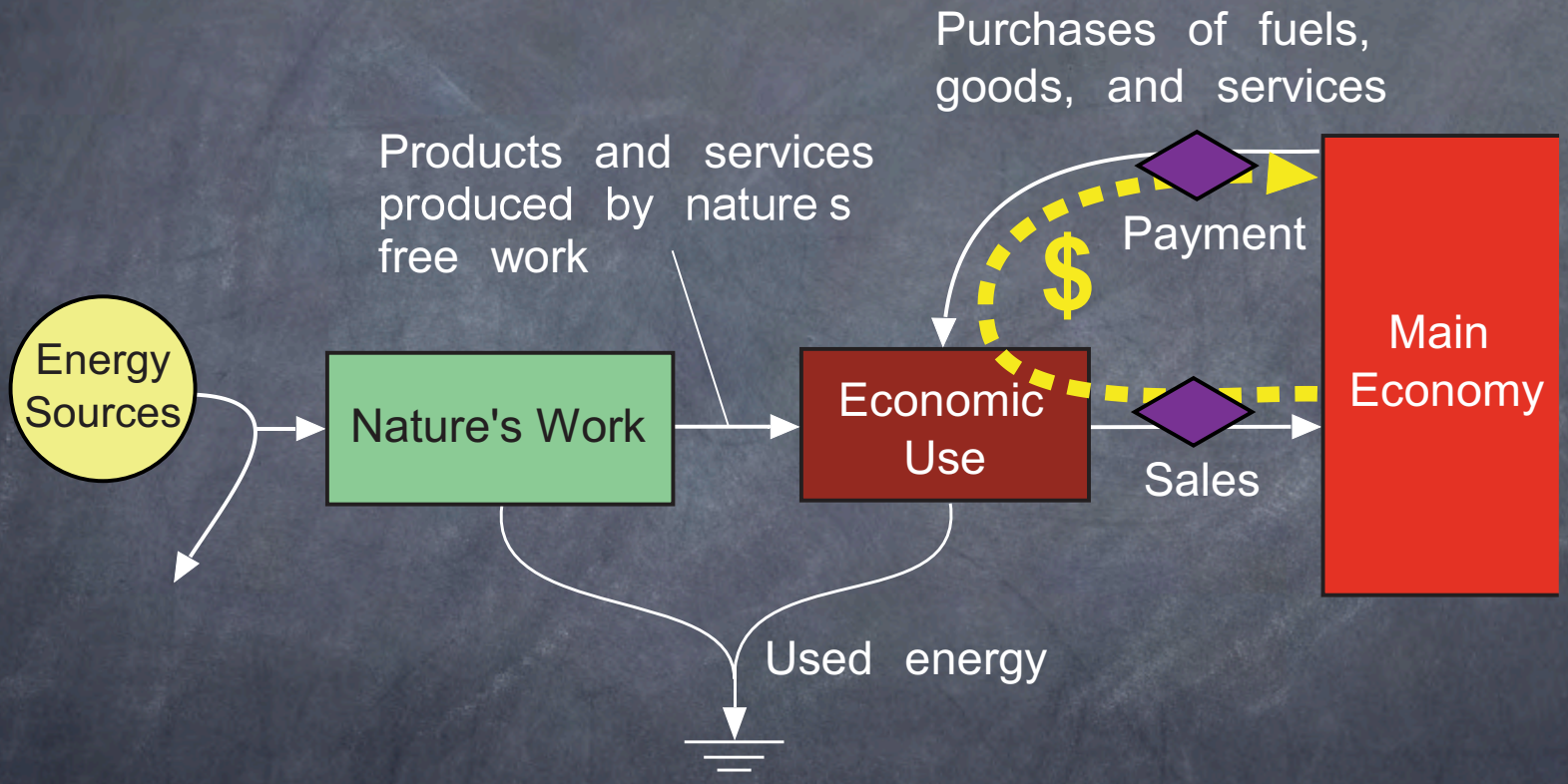
Introduction

- Masan Bay is one of the most polluted coastal waters in Korea due to heavy industrial, urban, and port developments over the past decades
  - Chronic summer hypoxia and red tide
  - End-of-pipe measures had not worked well in improving the environmental quality of the bay
- First coastal total pollutant load management system (TPLMS) in Korea implemented to improve conditions of the bay since 2007.
  - Goal : Water column COD at 1.85 mg/L in 2011 with the reduction of COD load of 4,503.41 kg/day, through extension of sewer coverage, advanced sewage treatment, and stream ecosystem restorations
- Emergy methodology was used for a preliminary evaluation of benefits and costs of the first coastal TPLMS to better understand its performance and ultimately provide policy insights for future coastal TPLMS.

Emergy Concept & Procedure

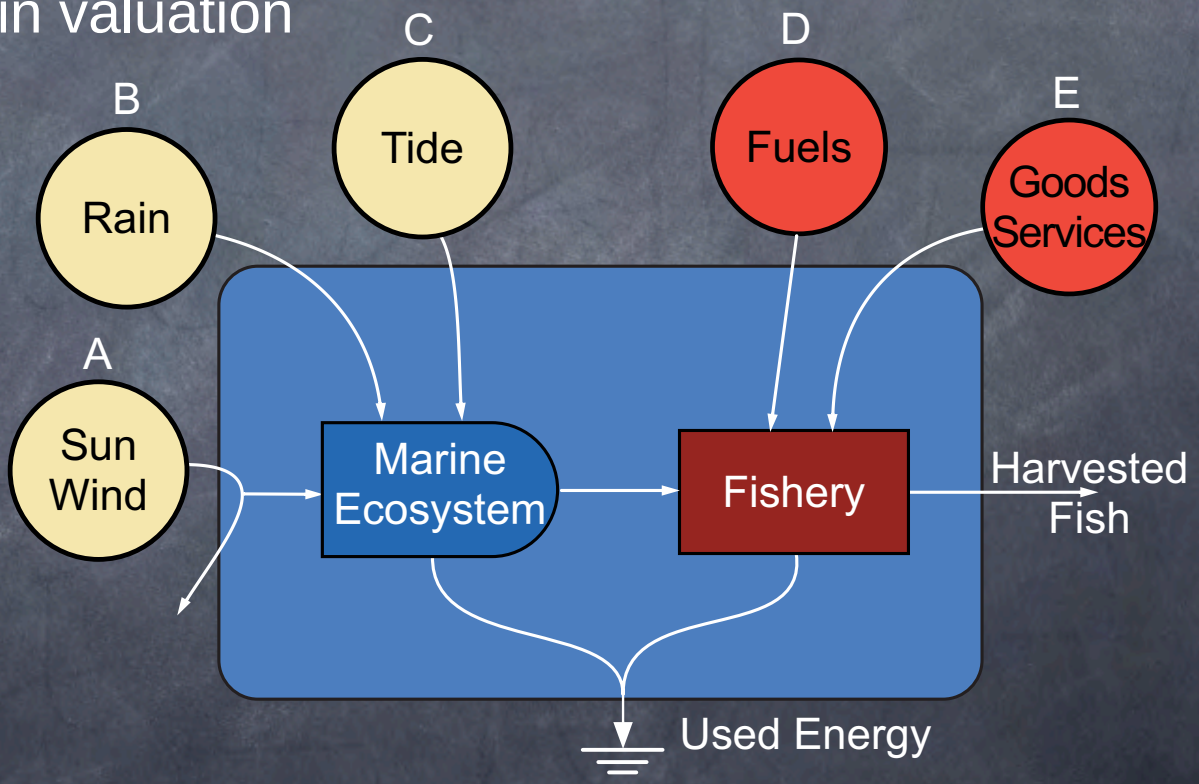
- How do we value things?
  - with money as the common denominator
  - based on willingness-to-pay of people



- Any other common denominators instead of money?
  - energy as an alternative because it is involved in every process on earth

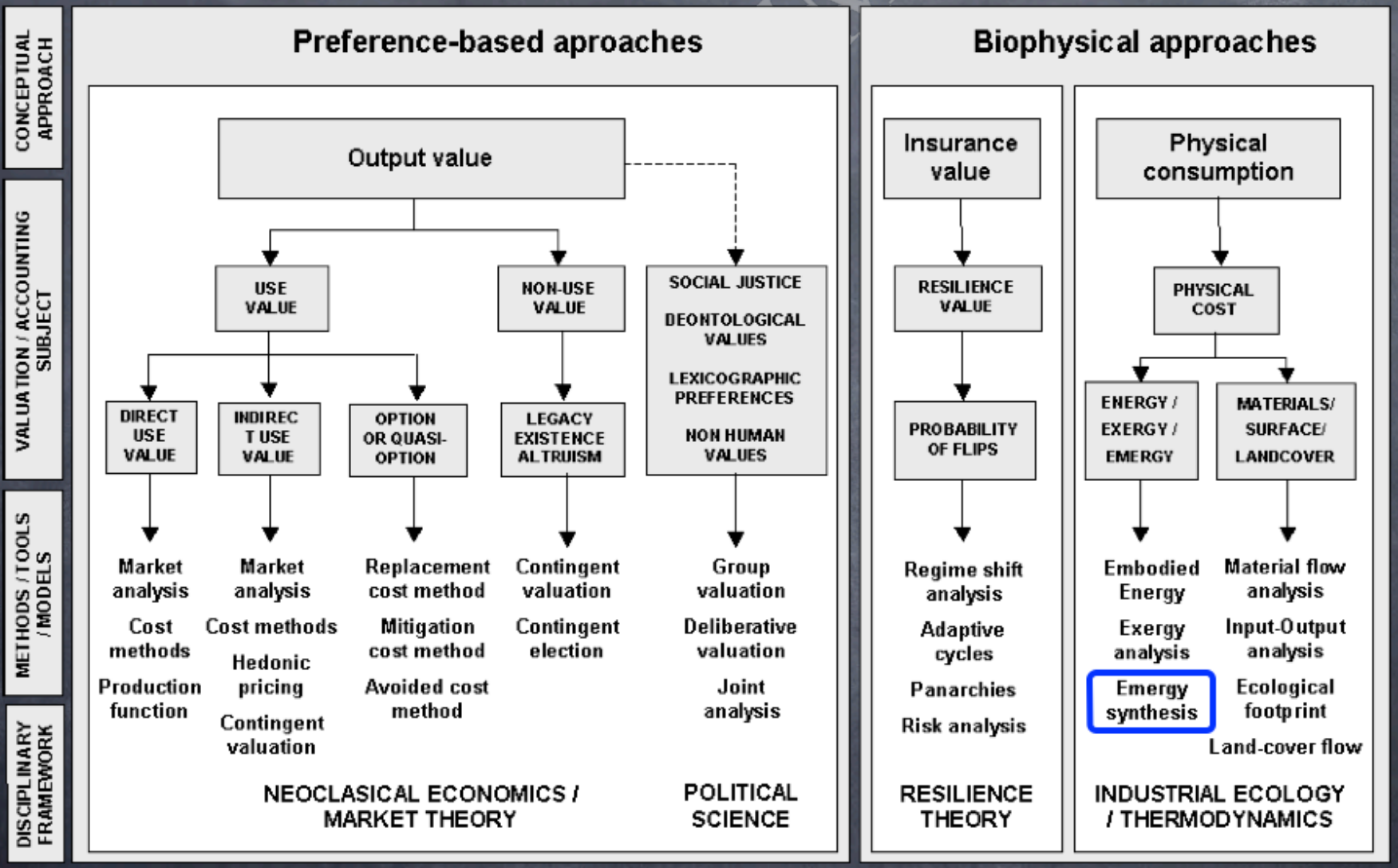
Emergy Concept & Procedure

- Energy memory
- "Available energy of one kind previously required directly and indirectly to make a product or service" (Odum, 1996)
  - Unit: emjoule, solar emjoule (sej)
- Biophysical approach in valuation



Solar emergy of harvested fish = Sum of all emergy inputs
A (or B, C) + D + E

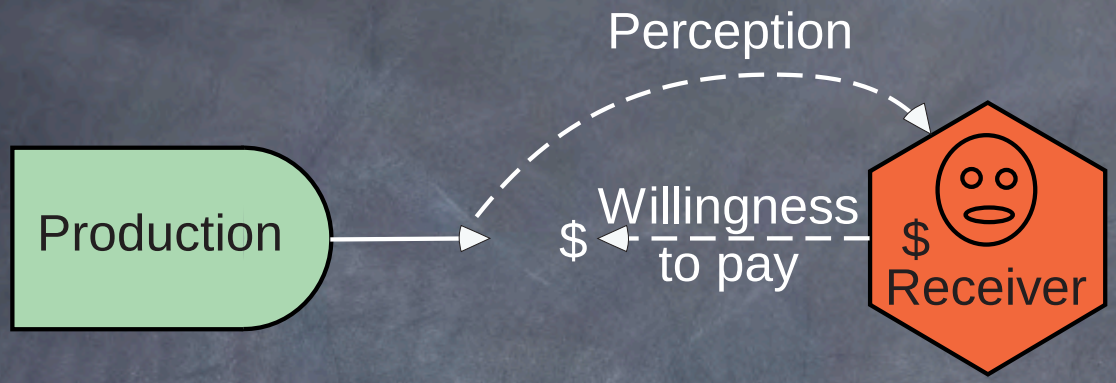
Emergy Concept & Procedure



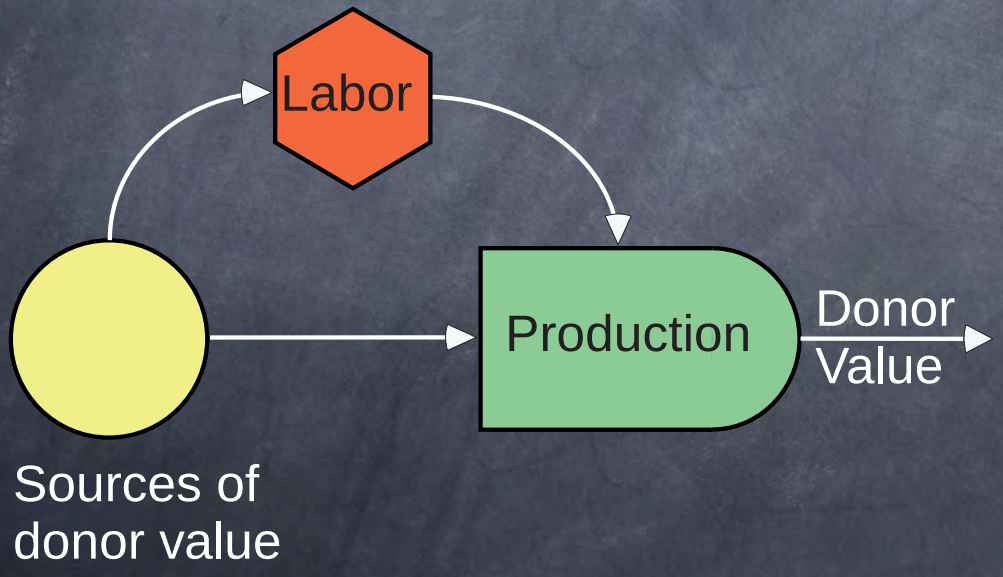
Source : TEEB (2010)

Emergy Concept & Procedure

- Donor Approach vs Receiver Approach in valuation



Receiver value:
Concept of a value originating from receiver perceptions



Emergy value:
Concept of a donor value originating from required inputs

Source: Odum (1996)

Emergy Concept & Procedure

- Energy quality
  - How do we compare different things?
  - How much money do I have?
    - $100 + ₩100 + €100 + ¥100 = 400 ???

  - Conversion factors needed to compare different things
    - Exchange rate as a conversion factor to compare different currencies
    - $100×1,055.20₩/$ + ₩100 + €100×1,033.39₩/€ + ¥100×9.64₩/¥ = ₩ 209,923
      (Exchange rate as of September 30, 2014)

Emergy Concept & Procedure

- Energy quality
  - Differences in the ability to do work among energies
  - Conversion factors needed to compare different energies
  - Unit emergy value: transformity (sej/J), specific emergy (sej/g), emergy-money ratio (sej/$), etc, with solar energy as the reference point

Sun	1	sej/J	Odum (2000)
Wind	2,450	sej/J	Odum (2000)
Rain	30,500	sej/J	Odum (2000)
Wave	51,000	sej/J	Odum (2000)
Tide	73,900	sej/J	Odum (2000)
Iron ore	5.78×10^{9}	sej/g	Cohen (2005)
Gold	5.04×10^{11}	sej/g	Cohen (2005)
EMR for Korea in 2011	5.42×10^{12}	sej/$	Kang (2013)

Emergy Concept & Procedure

- Emergy flow (sej/yr) = Biophysical flows (J/yr, g/yr, etc)
  × Unit emergy value (sej/J, sej/g, etc)
- Conversion of emergy value to money
  - Emvalue = Emergy flow / Emergy-money ratio

    ex) Emvalue of tidal energy in Korea in 2011 = 54.0×10^{9} em$/yr

    (2.89×10^{23} sej/yr) / (5.36×10^{12} sej/$)
  - Emergy-money ratio (EMR) = Total emergy used in an economy / GDP

    - Unit: sej/$, sej/₩, etc

    - EMR of Korea in 2011: 5.36×10^{12} sej/$

      Total emergy use (5.98×10^{24} sej/yr) / GDP (1.11×10^{12} $/yr)

Masan Bay TPLMS Evaluation

- Masan Bay area in 2010
  - Population: 1,103,849 people (2.3% of the country)
  - Area: 744.26 km2 (0.7% of the country)
  - GRDP: 30.4 trillion KRW (2.5% of national GDP)
  - 9 industrial complexes with a total area of 178.3 km^2
- Evaluation boundary
  - Masan Bay Total Pollution Load Management System
    - Marine area : 70.9 km^2
    - Land area : 263.98 km^2
  - COD reduction target
    - 4,503.41 kg/day
  - Evaluation period
    - 30 years (2011~2041)

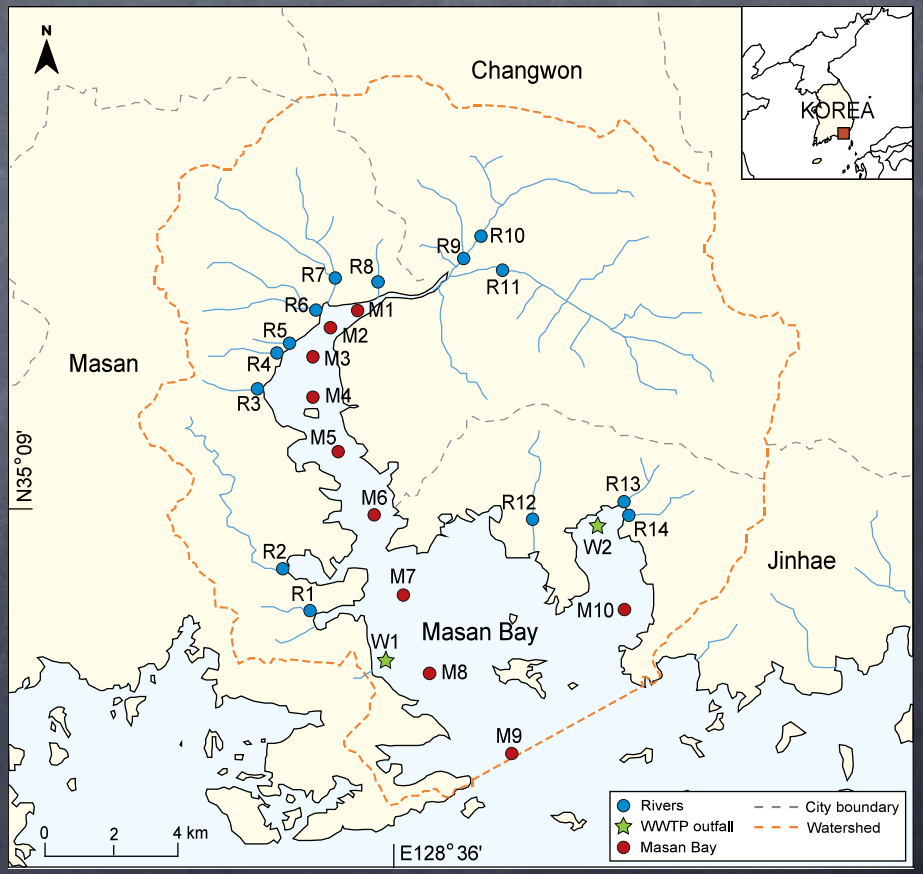


Figure from Chang et al. (2012)

Masan Bay TPLMS Evaluation

- Emergy costs and benefits of the Masan Bay TPLMS
  - Cost from an economic assessment (KMI, 2012)
    - Sewer coverage, advanced sewage treatment, stream restoration
  - Ony two benefits were considered in this study
    - Oxygen increase from decreased COD in the water column
    - Return of 5 endangered sp., 1 natural monument sp. to the bay

Items	Data		Unit Emergy Value		Emergy (sej)	Emvalue (million em$)	
						National	Local
Cost	3.22E+08	$/30 yrs	5.51E+12	sej/$	1.78E+21	322	322
Benefit					7.03E+20	128	332
Oxygen increase	4.93E+10	g/30 yrs	8.65E+07	sej/g	4.27E+18	1	2
Migrating birds	3	species	2.10E+20	sej/sp.	1.57E+20	29	74
Resident birds	2	species	2.10E+20	sej/sp.	4.19E+20	76	198
Crab	1	species	1.22E+20	sej/sp.	1.22E+20	22	58

- UEVs : species from Irvin (2000), oxygen from Ulgiati and Matias (2001), emergy-money ratios from Kang(2014)
- National: based on national EMR, Local: based on local EMR

Conclusions

- This study demonstrated that the emergy methodology could provide a useful tool in comparing the costs and benefits of coastal TPLMS implementation in Korea.
  - More coastal TPLMS are under development for other areas.
- However, limited data and information for the Masan Bay TPLMS did not allow for an in-depth analysis of TPLMS performance. The followings are needed to better understand the performance of coastal TPLMS and guide decision making process to improve it.
  - For costs, detailed data on material and energy required to implement measures to reduce pollutant input to the bay are needed
  - Other benefits should be included in the evaluation
  - Unit emergy values for protected or rare species in Korea need to be estimated

Thank you for your listening!