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RIWS-WHU

Research Institute
for Water Security
Wuhan University

Sefficiency

(Sustainable efficiency)

a Systemic Framework for

Advancing Water Security

Naim HAIE
Director, Executive Board of
International Water Resources Association (IWRA)
Civil Engineering Department, University of Minho, Portugal
naim@civil.uminho.pt

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Why Efficiency

"Efficiency is thus not a goal in itself. It is not something we want for its own sake, but rather because it helps us attain more of the things we value." Stone (2002)

Concept vs Computation

Classical Efficiency (CE)

$$CE = (ET - PP)_b / VA$$ **(or similar variations)**

much used: UN, China, EU, USA, etc.

CE is flawed

i. Lack of generalized application of Usefulness Criterion
ii. Mixing up of hydrology and agronomy
iii. Incompleteness of water flow considerations
iv. Objectives and scale mismatches

The Water Hierarchy

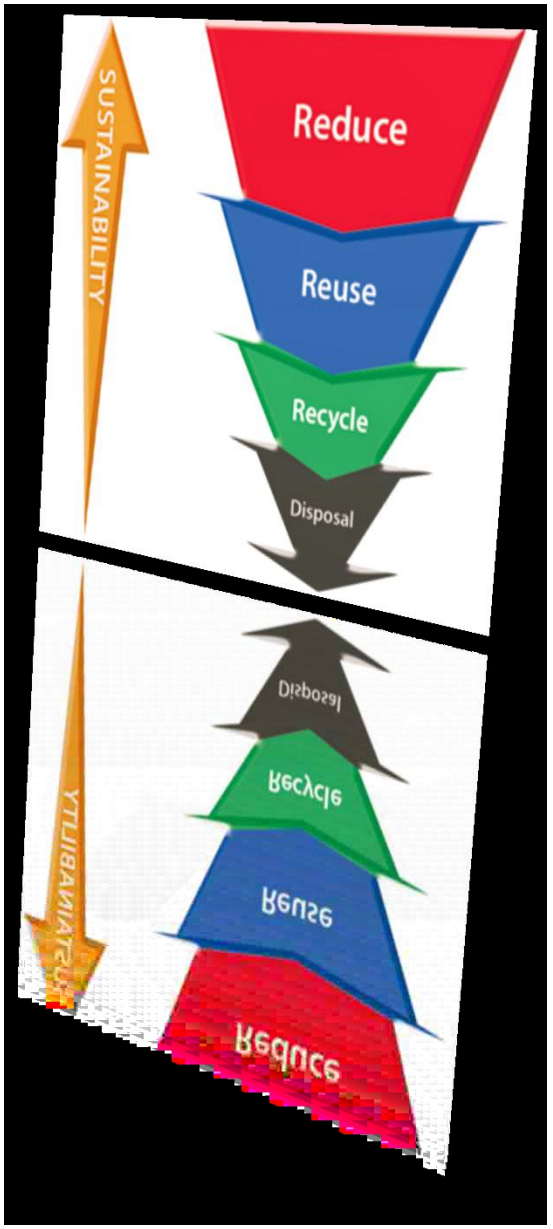
Demand side measures:

- Efficiency and water saving (i.e., eliminate, reduce, reuse, recycle)
- Pricing policies (effective water pricing policy and cost-effective alternatives)

Supply side measures (options):

- Infrastructures for "producing" water (dams, water transport between regions, desalinization, …)

(EC 2007)



Efficiency and Water Security

- Aiming "at increasing water security through increased water **efficiency**"
- "Addressing this security nexus [*Water, Energy, Food*] in a **holistic** manner will allow for greater **efficiency** based on **systems** thinking and prevent unintended **negative** externalities"
- Ensuring "equitable flow of **benefits**"

UN Water (2013) Water Security & the Global Water Agenda. A UN-Water Analytical Brief

Water Security: a working definition (UN-Water 2013)

The capacity of a population to safeguard sustainable access to

adequate **quantities** of acceptable **quality** water

for [*the following* ***benefits***]

- sustaining livelihoods
- human well-being
- socio-economic development
- protection against water-borne pollution
- protection against water-related disasters
- preserving ecosystems

in a climate of peace and political stability.

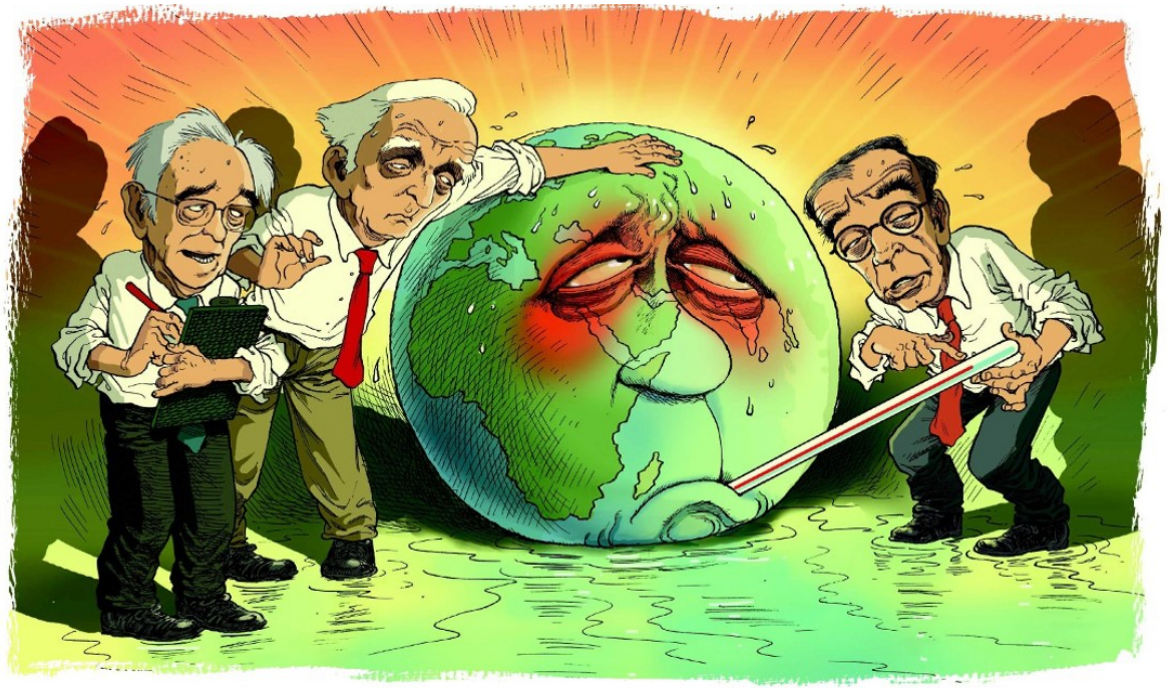
Efficiency expressions in water resources need certain requirements

Systemic
Comprehensive
Levels

Quantity
Quality
Benefits

Climate Change

Stakeholder

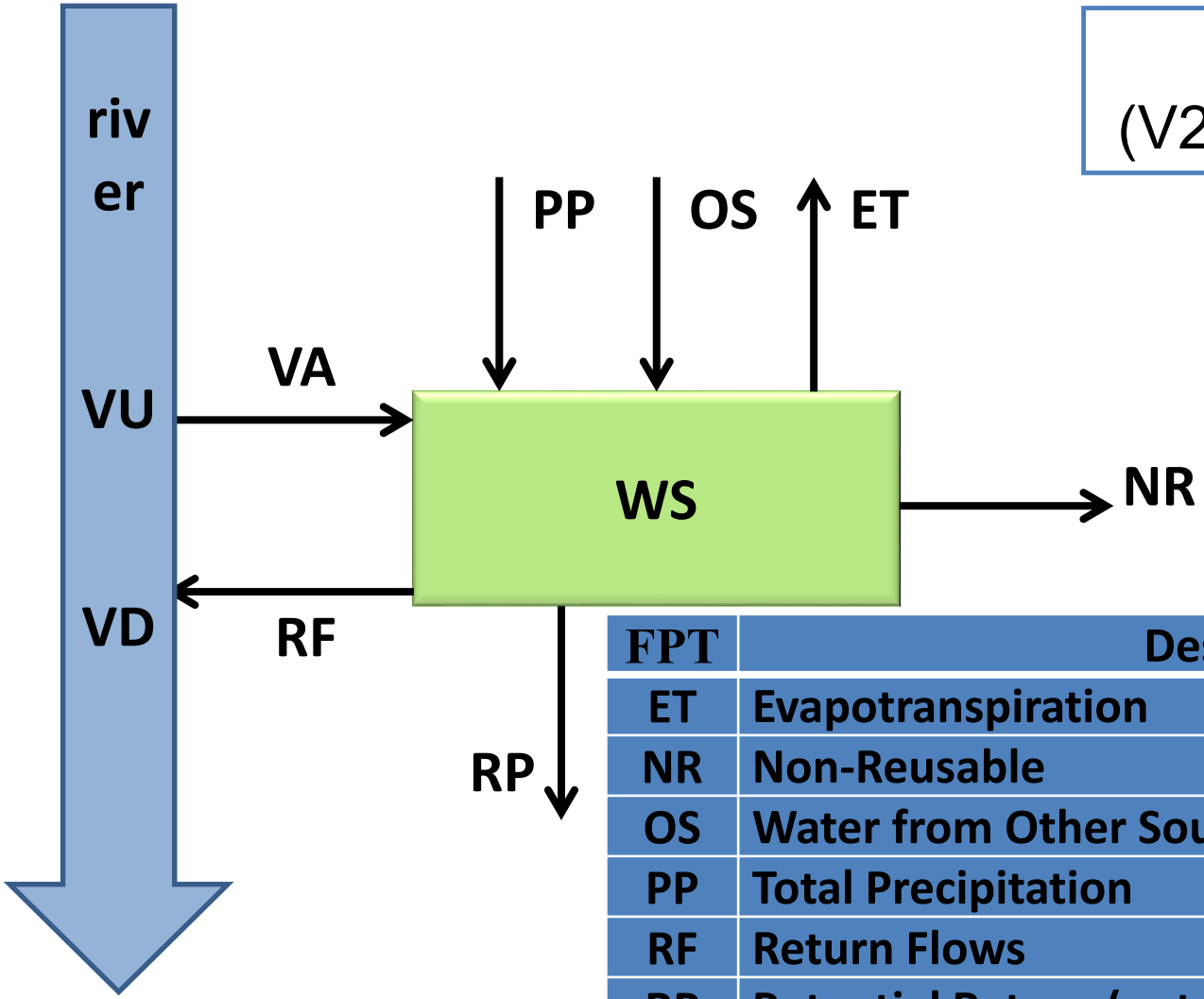


Cartoon is published in the Journal Nature; from Luiz Gylvan Meira Filho (2013)

Law of Mass Conservation
or
Water Balance

Water System (WS)

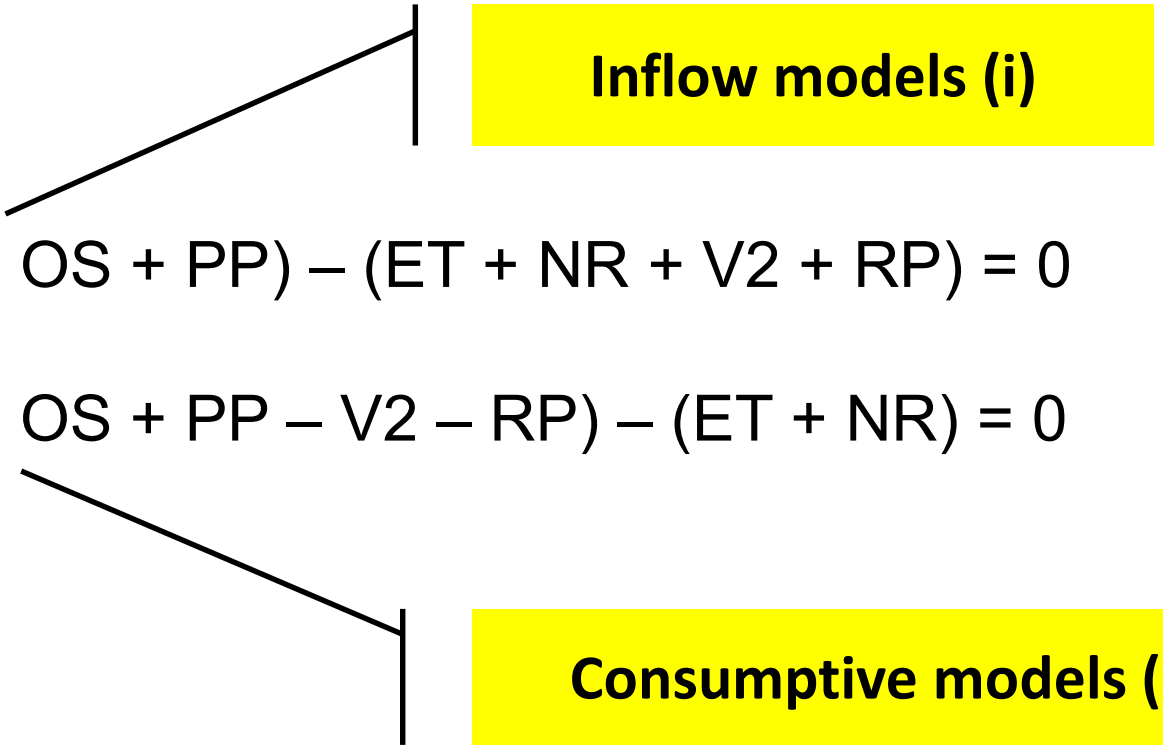
$$(V1 + OS + PP) - (V2 + RP + ET + NR) = 0$$



FPT	Description
ET	Evapotranspiration
NR	Non-Reusable
OS	Water from Other Sources
PP	Total Precipitation
RF	Return Flows
RP	Potential Return (not to the main source)
VA	Abstracted/Applied water from the main source
VD	Volume of water Downstream after RF
VU	Volume of water Upstream before VA
V1	Volume of water at section 1 (VU or VA)
V2	Volume of water at section 2 (VD or RF)

FPT=Flow Path Type

Water Balance

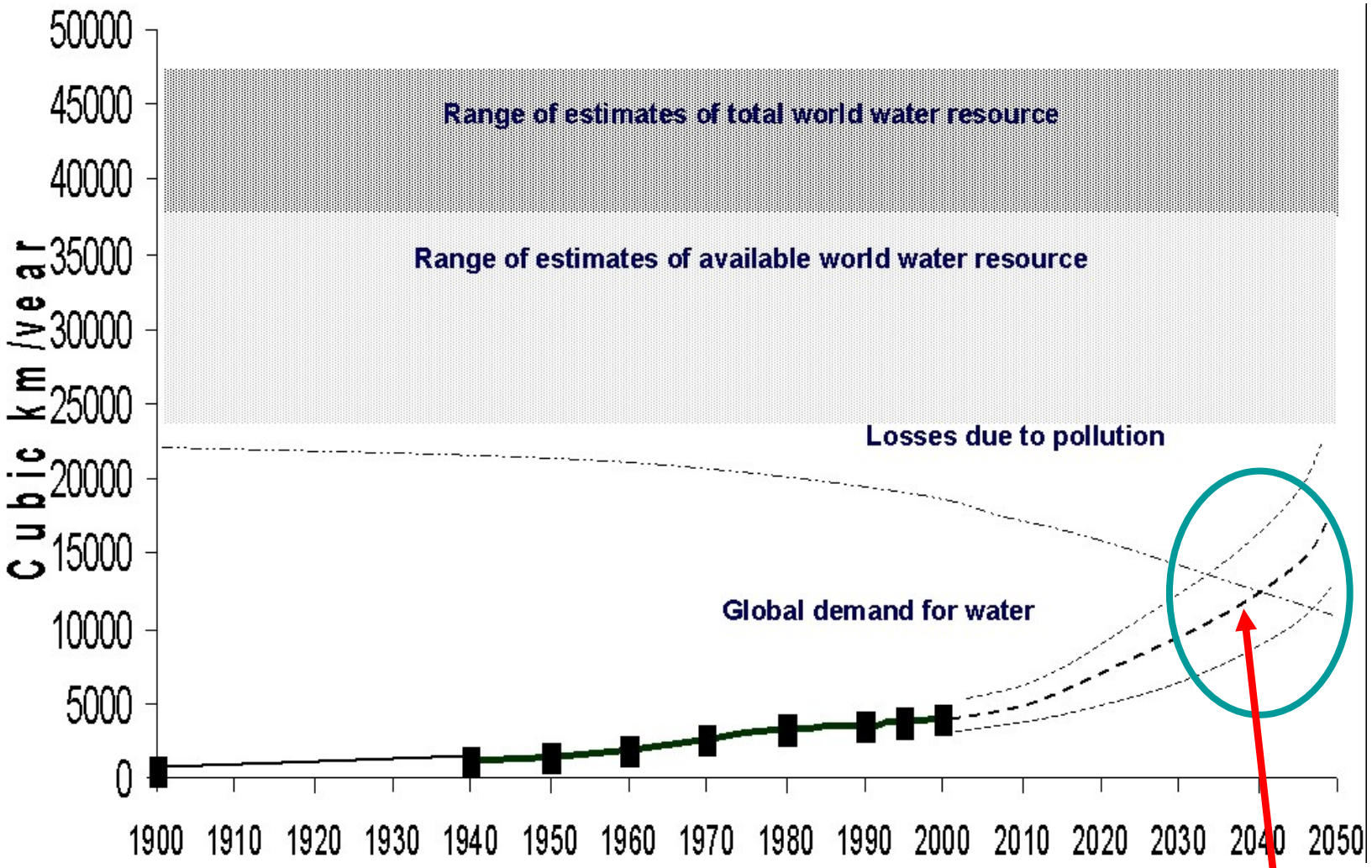


[(V1 + OS + PP) – c (V2 + RP)] – [(ET + NR) + i (V2 + RP)] = 0

i, c = 0 or 1 with i + c = 1

Water Quality

Water Crisis even without climate change!



Nobre, C (2011)

Possible Efficiency Benefits

- Protect environment
- Reduce new infrastructure
- Save energy
- Decrease cost (individual consumers pay less)
- Rationalize investments
- Support economic growth
- Create jobs
- Improve cost effectiveness of water service
- Adapt to uncertainty (e.g., climate change)
- Lessen impact of severe conditions
- Allocate water better
- Minimize the risks of water scarcity
- Enhance conditions for recreation

Possible beneficial and non-beneficial uses of FPTs

	ET	NR	R
Beneficial	• ET (crop, landscape) • Evaporation for climate control	• Non-reusable deep percolation for salt control (leaching) • Virtual water	• Reusable deep percolation for salt control (leaching)
Non-beneficial	• ET (Phreatophyte) • Evaporation (sprinkler, reservoir, excess wet soil)	• Non-reusable excess deep percolation • Runoff or spills to salt sinks	• Reusable excess deep percolation • Reusable runoff • Reusable canal spills

Usefulness Criterion

$X_q = W_qX * X$

$X_b = W_bX * X$

$X_S = W_SX * X$

$W_SX = W_qX * W_bX$

W_q = quality weight

W_b = beneficial weight

W_S = usefulness weight

X = an FPT

Sefficiency

Macro, Meso, and Micro-Efficiency (3ME)

Efficiency (%) defined:
ratio of useful outflow to its corresponding total flow

Applying Usefulness Criterion to the combined Water Balance equation would give efficiency.

(mathematical proof in the paper)

$$\mathrm{MacroE_S} = \left[\frac{\mathrm{ET} + \mathrm{NR} + \mathrm{i}\left(\mathrm{VD} + \mathrm{RP}\right)}{\mathrm{VU} + \mathrm{OS} + \mathrm{PP} - \mathrm{c}\left(\mathrm{VD} + \mathrm{RP}\right)} \right]_{\mathrm{S}}$$

- Macro-Efficiency (MacroE): indicates the impact of a WS on a basin, e.g., the major river where water was abstracted.

$$\mathrm{MesoE_S} = \left[\frac{\mathrm{ET} + \mathrm{NR} + \mathrm{i}\left(\mathrm{RF} + \mathrm{RP}\right)}{\mathrm{VA} + \mathrm{OS} + \mathrm{PP} - \mathrm{c}\left(\mathrm{RF} + \mathrm{RP}\right)} \right]_{\mathrm{S}}$$

- Meso-Efficiency (MesoE): indicates, for example, the impact of return flows generated by a WS.

$$\mathrm{MicroE_S} = \left(\frac{\mathrm{ET} + \mathrm{NR}}{\mathrm{VA} + \mathrm{OS} + \mathrm{PP}} \right)_{\mathrm{S}}$$

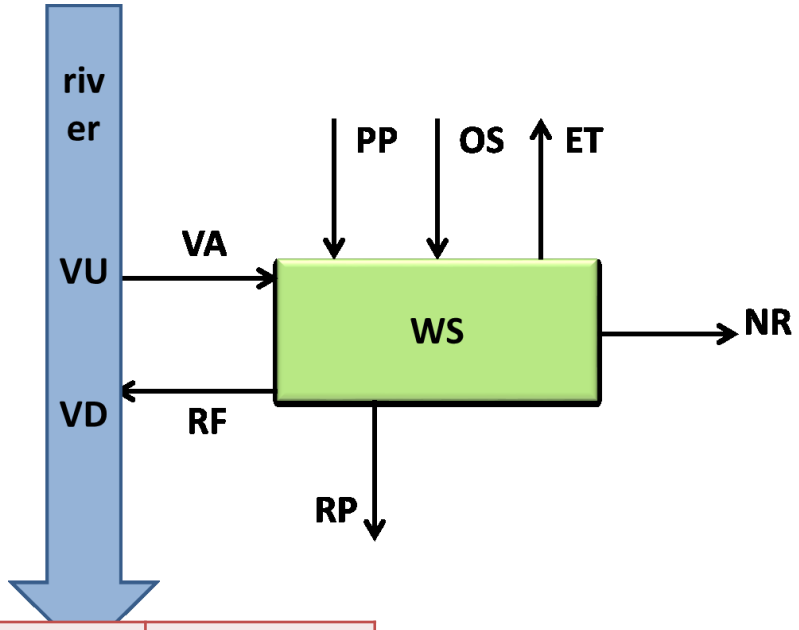
- Micro-Efficiency (MicroE): indicates the useful outflow generated by a WS for itself.

Haie and Keller (2012 or 2014)

Simple Example

	quantity	Wq	Wb
ET	185000	1	0.87
NR	0	1	0
OS	0	0	1
PP	0	1	0
RF	420000	0.63	1
RP	0	0	1
VA	605000	0.86	1
VD	4815000	0.84	1
VU	5000000	0.86	1

(ha-m/yr)



	%
i = 1	
MacroEs	98
MesoEs	81
MicroEs	31
c = 1	
MacroEs	63
MesoEs	62
MicroEs	31

Thank you!

More info: https://sites.google.com/site/naimhaie5