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#EU GREEN WEEK

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Evaluating Circular Water Economy Models at the Watershed Scale: A Carbon Emissions-Based Framework within the Water-Energy-Food-Ecosystem Nexus

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THE WATER-ENERGY-FOOD NEXUS: BUILDING RESILIENCE TO GLOBAL CHALLENGES

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INTRODUCTION

Green Deal and Circular Economy

Various approaches to achieving SDGs and WFD targets under the WEFE Nexus framework.

such as

The *European Green Deal (2019)* aims

- to restore biodiversity
- to cut pollution
- to keep resources in economic cycles as long as possible
- to accomplish a modern, resource-efficient, and competitive economy

Circular Economy (10R)

Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover

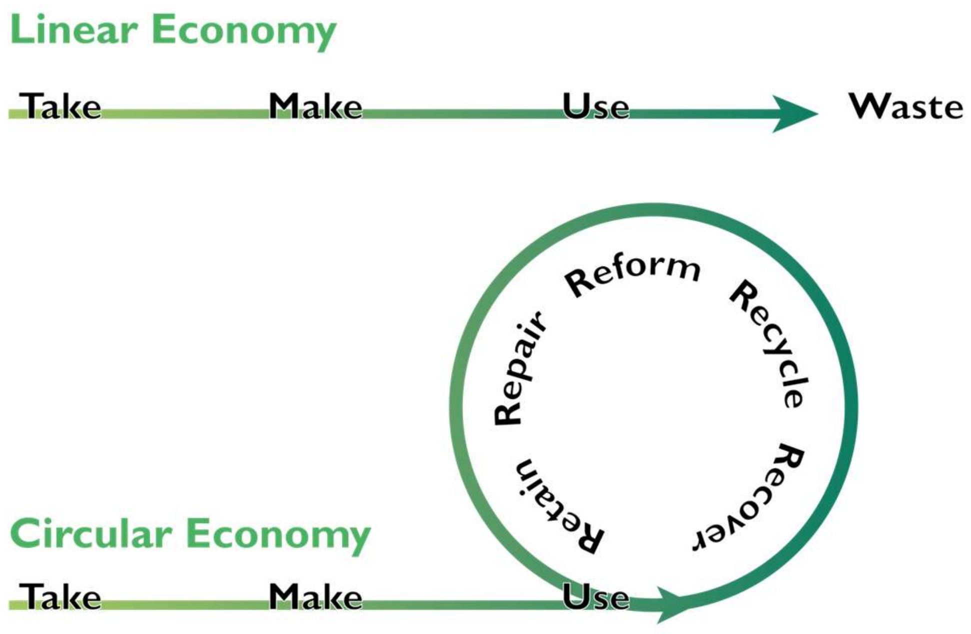

Figure 1. Difference between Linear Economy and Circular Economy (ReMade-Roject,,n.d.)

Aim of The Study:

- To create a systematic framework for assessing the performance of *circular water economy models* at watershed scale within the Water-Energy-Food-Ecosystem Nexus.
  - ✓ For this purpose, Multi-Criteria Decision Making is used.

Contributions to literature gap:

- *circular **water** economy on **macro** scale*
- *by using environmental and economic indicators*
  - ***basin-specific indicators***
- *by examining the impact of circular water economy models on **environmental flow***

Circular Water Economy:

Table 1. Principles of Circular Water Economy (Morseletto et al., 2022; Morseletto, 2019; Minguez et al., 2021; Reike et al., 2018; Vermeulen & Witjes, 2019; Smol et al., 2020)

Name of Principle	Definition
Refuse	Preventing the use of water
Rethink	Re-design/restructuring of the operational elements of water utilization, including practices, procedures, regulations, facilities, and technology
Reduce	Using less water, extracting less water from the source and using water efficiently
Reuse	Second or further use (by another user/owner) of water
Recycle	Second or further use (by the same user/owner) of water
Recover	Retrieval of valuable materials (i.e. organic matters, chemical elements, biochemical compounds) and the retention or generation of energy
Replenish	Restoring water that has been consumed by human activities back to natural ecosystems

Figure 2. Levels in Circular Economy (Vanhamäki et al., 2019)

Method Selection:

Advantages of MCDM over other methods:

- in terms of time and budget
- possibility of evaluating macro systems
- possibility of evaluation from both environmental and economic aspects
- need of less data

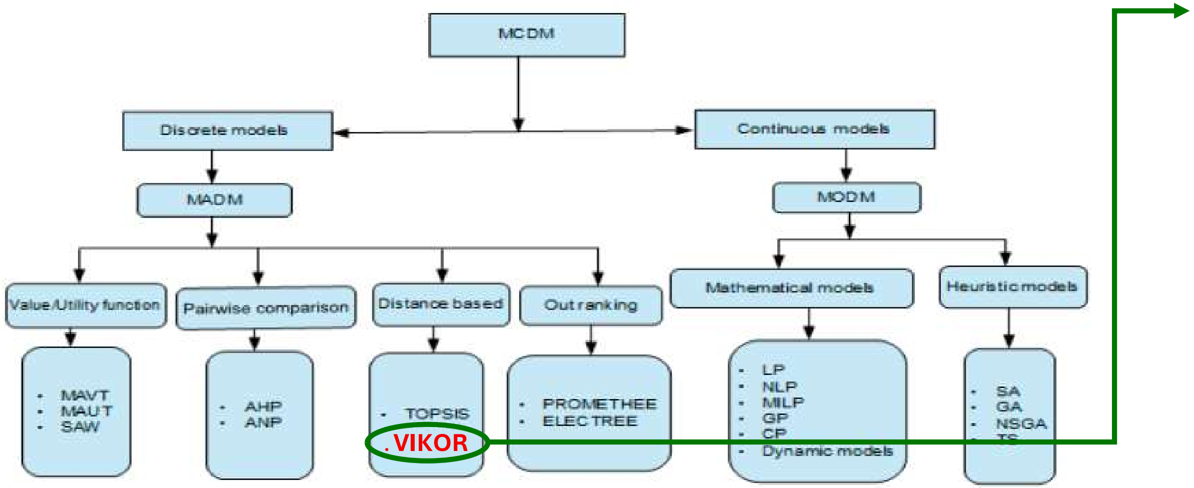

Figure 3. Multi-Criteria Decision Making Methods (Gebre et al., 2021)

Reasons for Selecting Extended VIKOR:

VIKOR:

- numerical evaluation
- allows for the joint evaluation of multiple criteria in the presence of conflicting criteria
- provides a balanced assessment
- useful in complex systems

Extended VIKOR:

- using interval numbers, indicating data uncertainty or imprecision

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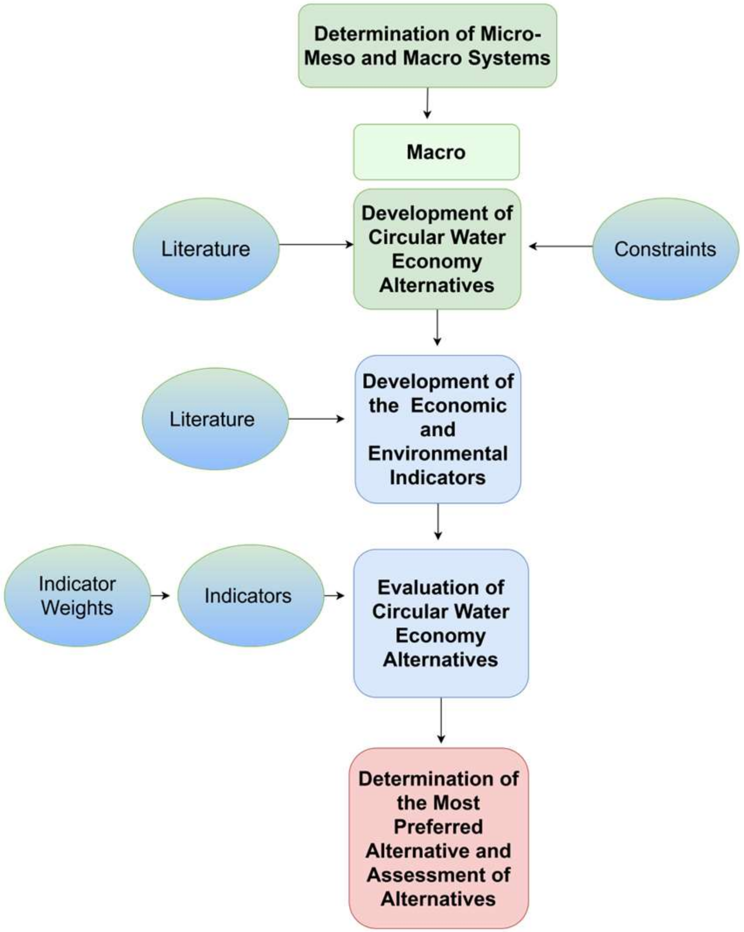
METHODOLOGY

Overview of Methodology



WHY PORSUK SUB-BASIN?

- ✓ Surface Water - Porsuk Dam (Eskişehir's Drinking Water Source): by 2045 and 2065, the dam is projected to be unable to fully meet irrigation water demands
- ✓ Groundwater: In some of plains, allocations have exceeded plain reserves
- ✓ Semi-arid Watershed

Development of Circular Water Economy Scenarios & Used Principles

Urban Sector:

- Utilization of domestic treated wastewater in city parks and green areas ***(Reuse)***

Agricultural Sector:

- Utilization of domestic treated wastewater for agricultural irrigation ***(Reuse)***

Industrial Sector:

- Utilization of domestic treated wastewater in industrial processes and other industrial uses ***(Reuse)***
- Utilization of industrial treated wastewater in industrial processes and other industrial uses ***(Recycle)***

Discharge:

- Controlled discharge into the natural receiving environment ***(Replenish)***

In all of sub-basin: ***Reduction+Replenish***

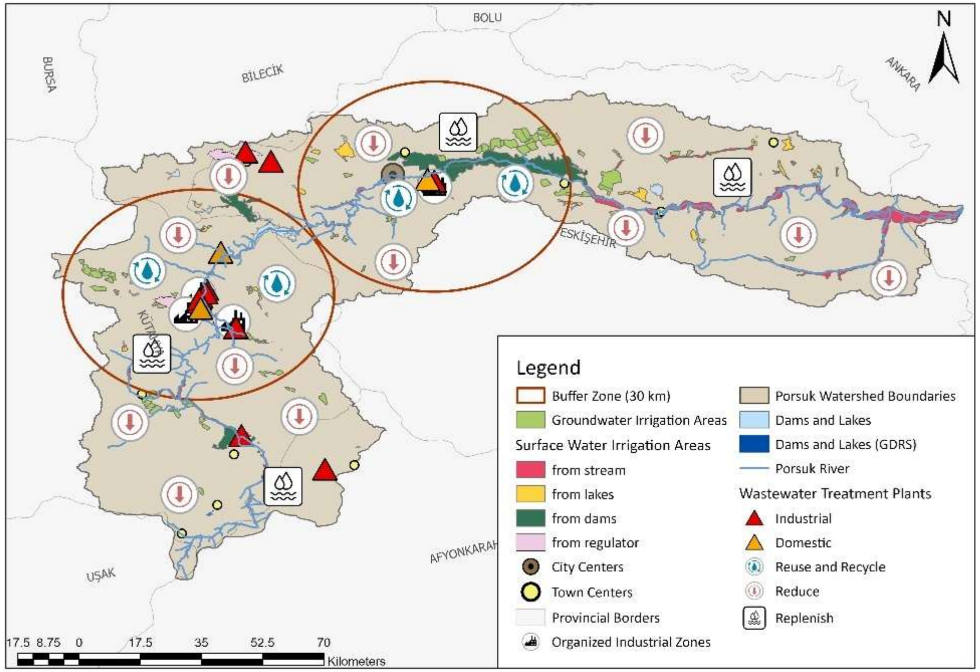


Figure 4. Illustration of Circular Water Economy Principles in the Porsuk Sub-basin

Development of Circular Water Economy Alternatives

Reduction Ratios

- implementation of hybrid cooling towers and process-based enhancements → 15% reduction
- prevention of losses and leaks → in Eskişehir: 25% reduction; in Kütahya: 35% reduction
- adoption of efficient smart landscaping techniques → 20% reduction
- SW: improvements in transmission lines: 30% reduction
- GW: application of surface irrigation methods and other enhancements: 20% reduction

Reuse + Recycle + Replenishment Proportions

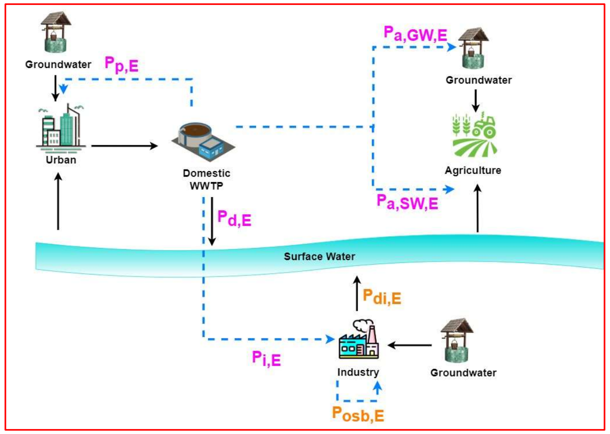


Figure 5. Representation of Variables in Circular Water Economy Alternatives in Eskişehir

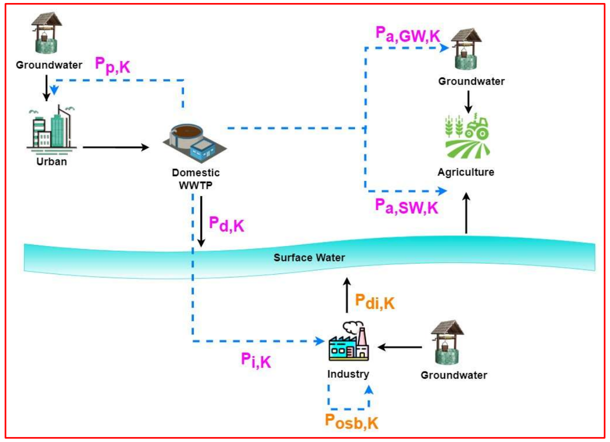
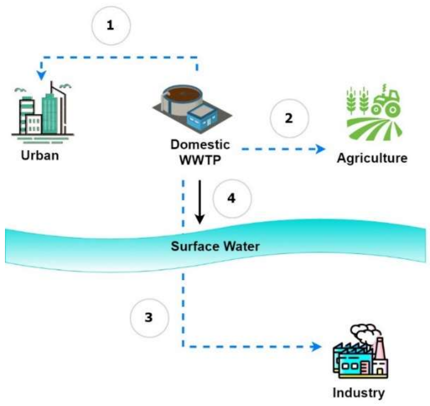


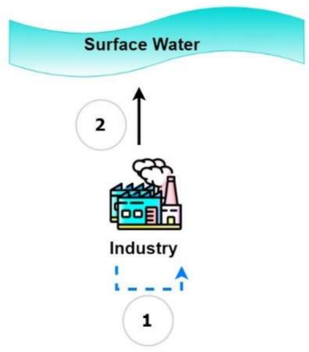
Figure 6. Representation of Variables in Circular Water Economy Alternatives in Kütahya

Development of Constraints

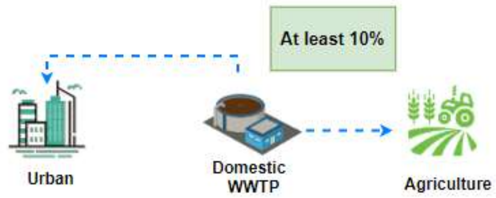
- water supply/demand balance → water should not be allocated to sectors in excess of their needs

- mass balance
  - portion of domestic wastewater sent to all sectors should be equal to 1
  - portion of industrial wastewater sent to all sectors should be equal to 1





- legal requirementments
  - not used for drinking purposes
  - at least 10% of domestic WWTP to park and agriculture



Development of Constraints

- required treatment technologies →

Table 2. Required Treatment Levels for Macro-Level Cross-Sectoral Symbioses (Republic of Türkiye, 2010; A. Olgaç, personal communication, February 7, 2024, Yüksel Project)

Source	Recipient	Treatment Level
Domestic WWTP	Industry (Cooling Water)	Disc Filter + Disinfection
Domestic WWTP	Industry (Process Water)	Ultrafiltration + Disinfection + Reverse Osmosis
Domestic WWTP	Agriculture (Class A)	Disc Filter + Disinfection
Domestic WWTP	Agriculture (Class B)	Disinfection
Organized Industrial Zone WWTP	Industry (Cooling Water)	Disc Filter + Disinfection
Organized Industrial Zone WWTP	Industry (Process Water)	Ultrafiltration + Disinfection + Reverse Osmosis

- groundwater level → groundwater extraction amounts < groundwater potential

- environmental flows → surface water extraction amounts < surface water potential
  &
  EFR should be satisfied

Development of Circular Water Economy Alternatives

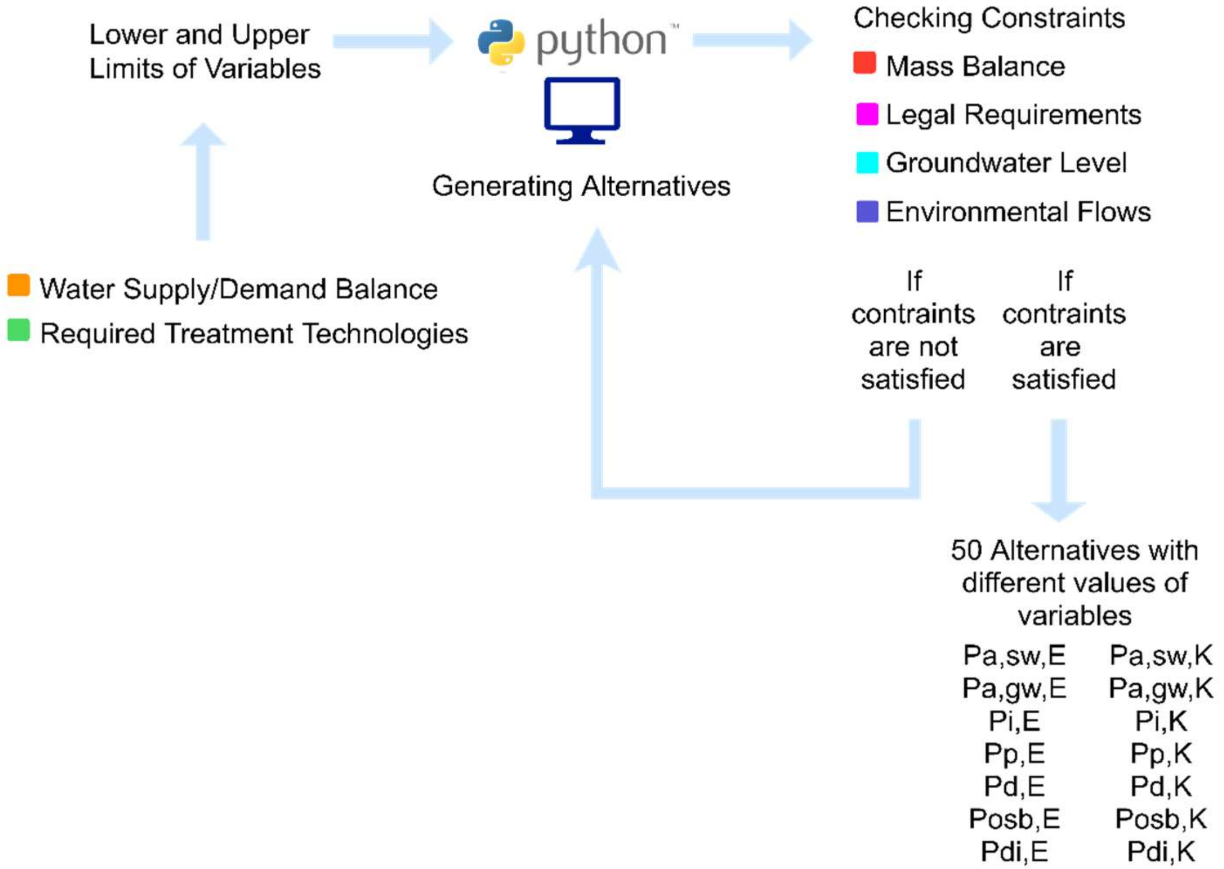


Figure 7. The Algorithm for the Development of Alternatives

1 alternative : Business As Usual (BAU) (S0-B)

1 alternative : with Reduce + Replenish (SR)

50 alternatives : with Reduce + Reuse + Recycle + Replenish (SR-R3, SR-R4,.....SR-R52)

Evaluation of Circular Water Economy Alternatives

Development of Indicators

input for

Stakeholder system analysis
Sectoral system analysis

A- Economic Indicators

1- Water Productivity for Eskişehir and Kütahya (+)
2- Total Cost of Wastewater Treatment and Distribution for Eskişehir and Kütahya (-)
3- Total Cost of Water Tariffs for Eskişehir and Kütahya (-)
4-Economic Benefit for Eskişehir and Kütahya (+)

B- Environmental Indicators

1- Portion of Groundwater Utilized for Eskişehir and Kütahya (-)
2- Portion of Surface Water Utilized for Porsuk Sub-basin (-)
3- CO_2 Emission (-)

Evaluation of Circular Water Economy Alternatives

1- Water Productivity (+) → GDP of the sector & Q_{used} & $Q_{reused,recycled}$

2- Total Cost of Wastewater Treatment and Distribution (-) →
- Treatment Cost (Treatment method and $Q_{reused,recycled}$)
- Piping Cost (Distance and $Q_{reused,recycled}$)
- Pumping Cost (Head difference, distance and $Q_{reused,recycled}$)
- Excavation & Filling Cost (Distance)

3- Total Cost of Water Tariffs (-) →
- Water Abstraction Cost ($Q_{withdrawal}$)
- Cost because of buying recycled water from WWTP ($Q_{reused,recycled}$)

4-Economic Benefit (+) →
- Revenue because of selling wastewater ($Q_{reused,recycled}$)
- Energy Discount due to Reuse in WWTP ($Q_{reused,recycled}$)

5- Portion of Groundwater Utilized (-) → $Q_{reused,recycled}$

6- Portion of Surface Water Utilized (-) → $Q_{reused,recycled}$, SW Potential, EFR, Downstream Water Demand

7- CO_2 Emission (-) →
- Emission due to Treatment (Treatment method and $Q_{reused,recycled}$)
- Emission due to Pumping Cost (Head difference, distance and $Q_{reused,recycled}$)

RESULTS AND DISCUSSION

Evaluation of the Circular Water Economy Alternatives

Ranking of the Circular Water Economy Alternatives

Q_L and Q_U values of alternatives are calculated

↓

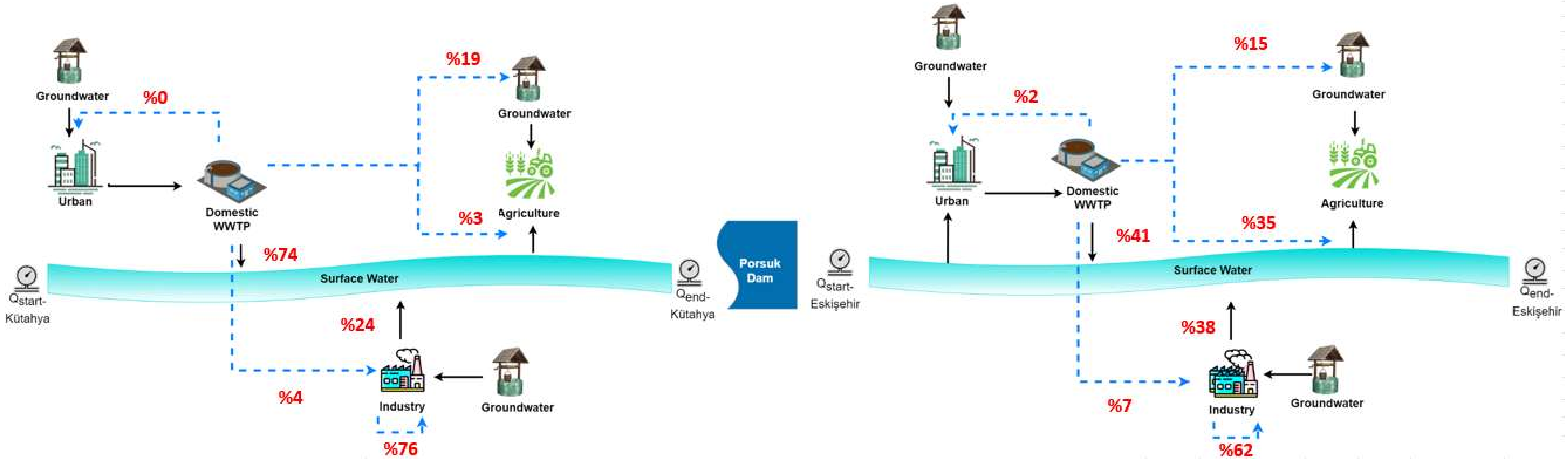
Alternatives are subsequently ranked from 1 to 52 using the *degree of possibility method*

the first alternative representing (w/ lowest Q values): the most preferred alternative	the 52nd indicating (w/ highest Q values): the least preferred alternative

1. Initially, weights of indicators are same and 0.077 (13 indicators total)
2. Then, for an alternative where the importance of indicators changes, assigning a weight of 1 to certain indicators and 0 to others highlights their influence.

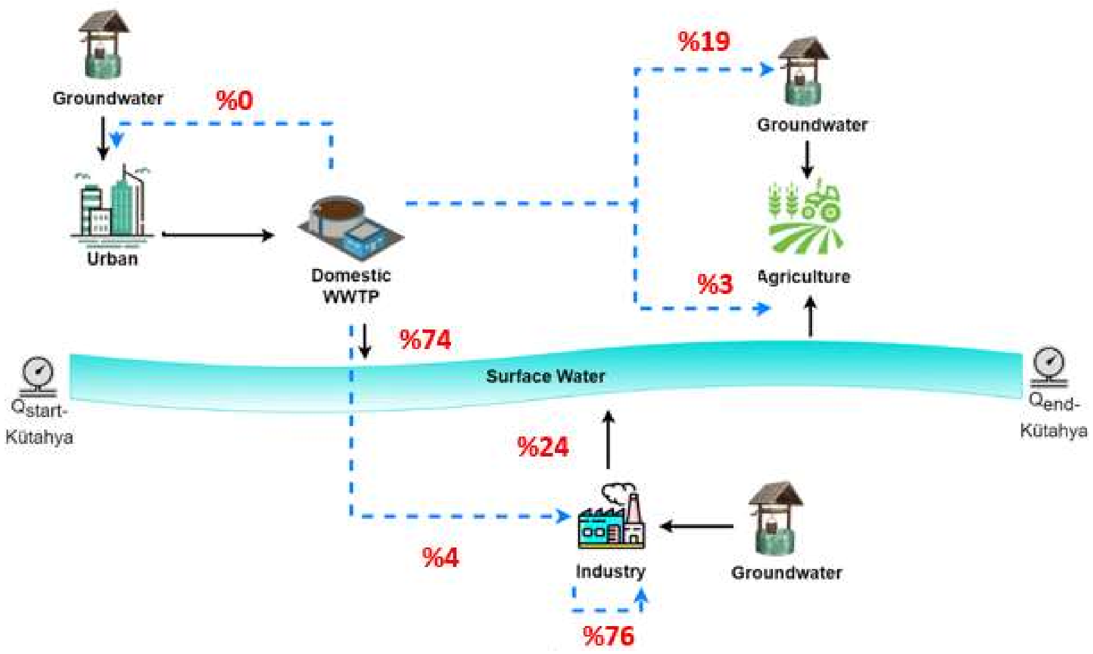
Evaluation of the Circular Water Economy Alternatives

Most Preferred Alternative:



Evaluation of the Circular Water Economy Alternatives

Most Preferred Alternative- Kütahya:

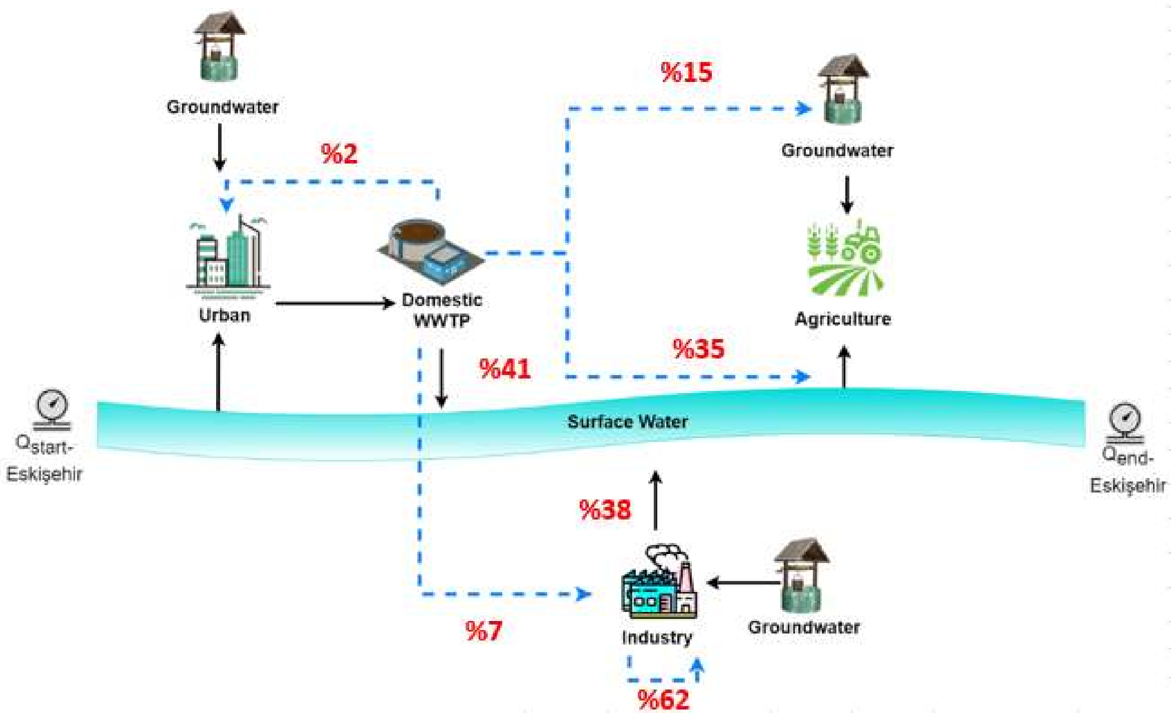


- Domestic WWTP
  - ✓ 74% → Discharge (Replenish)
  - ✓ 4% → OIZ (Reuse)
  - ✓ 3% → Agriculture (SW) (Reuse)
  - ✓ 19% → Agriculture (GW) (Reuse)

- OIZ WWTP
  - ✓ 24% → Discharge (Replenish)
  - ✓ 76% → OIZ (Recyle)

Evaluation of the Circular Water Economy Alternatives

Most Preferred Alternative- Eskişehir:



- Domestic WWTP
  - ✓ 41% → Discharge (Replenish)
  - ✓ 7% → OIZ (Reuse)
  - ✓ 35% → Agriculture (SW) (Reuse)
  - ✓ 15% → Agriculture (GW) (Reuse)
  - ✓ 2% → Park (Reuse)

- OIZ WWTP
  - ✓ 38% → Discharge (Replenish)
  - ✓ 62% → OIZ (Recyle)

Evaluation of the Circular Water Economy Alternatives

Most Preferred Alternative:

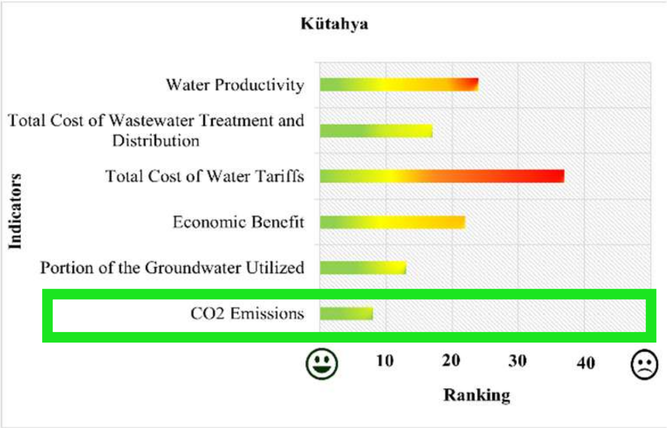


Figure 8. Indicator Ranking of the Most Preferred Alternative for Kütahya

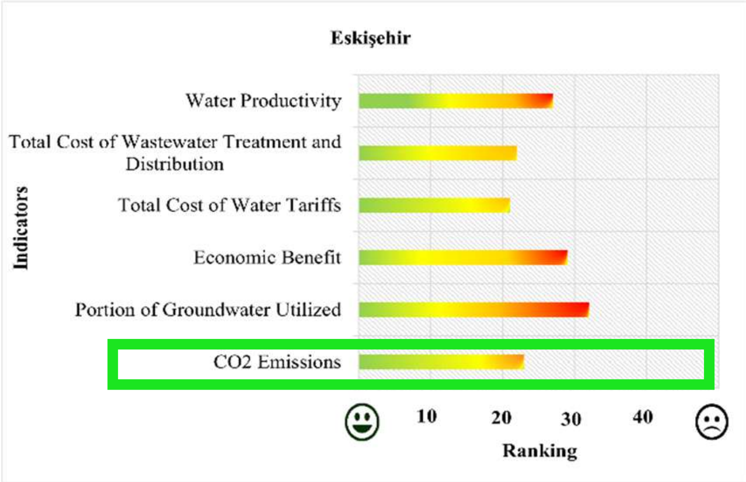


Figure 9. Indicator Ranking of the Most Preferred Alternative for Eskisehir

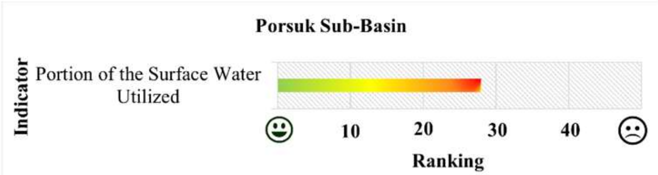


Figure 10. Indicator Ranking of the Most Preferred Alternative for the Porsuk Sub-basin

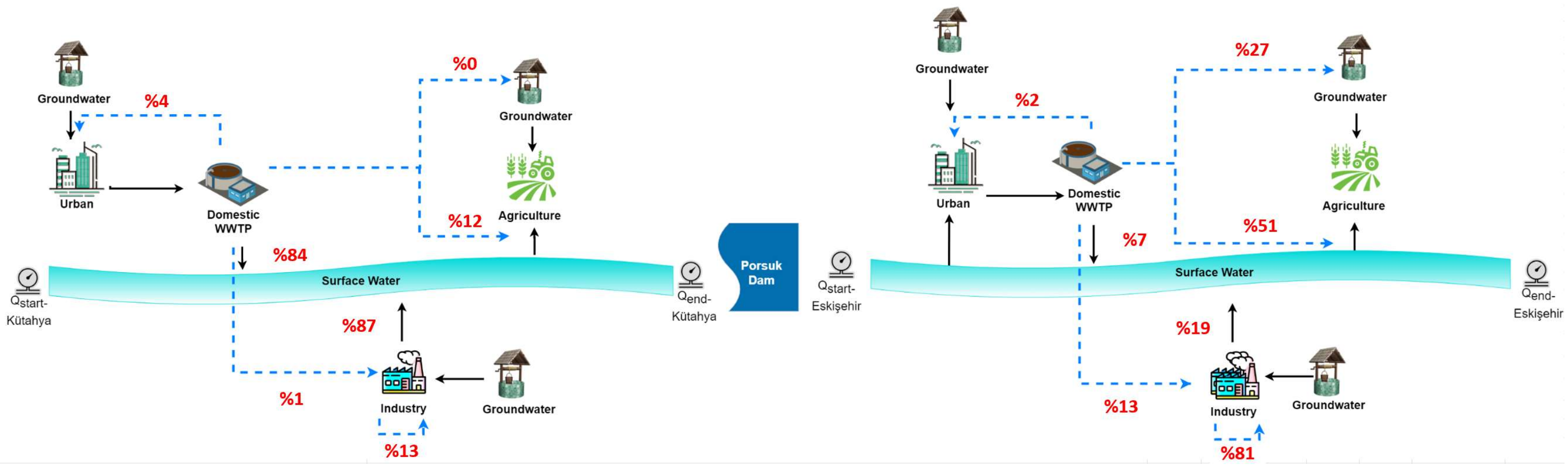
Since equal weight is given to the indicators

↓

no single indicator dominates an alternative

Indicator Based Evaluation of the Circular Water Economy Alternatives

Most Preferred Alternative in terms of **CO_2 Emission** (after S0-B and SR alternatives) (SR-R32)



- Higher WW ratios sent from Domestic WWTP to Agriculture (SW) wrt BAU
- Higher discharge ratios from OIZs to SW wrt BAU for Kütahya
- Higher recycle ratios in Eskişehir OIZ wrt BAU

Evaluation of the Circular Water Economy Alternatives in terms of Naturalized Stream Flow- Annual Average

Naturalized flows: the flow conditions in the absence of anthropogenic influences

Environmental flows: the quantity of freshwater necessary to sustain aquatic ecosystems

In 51 out of 52 alternatives, a **sustainable result** was observed by considering naturalized annual average streamflow values

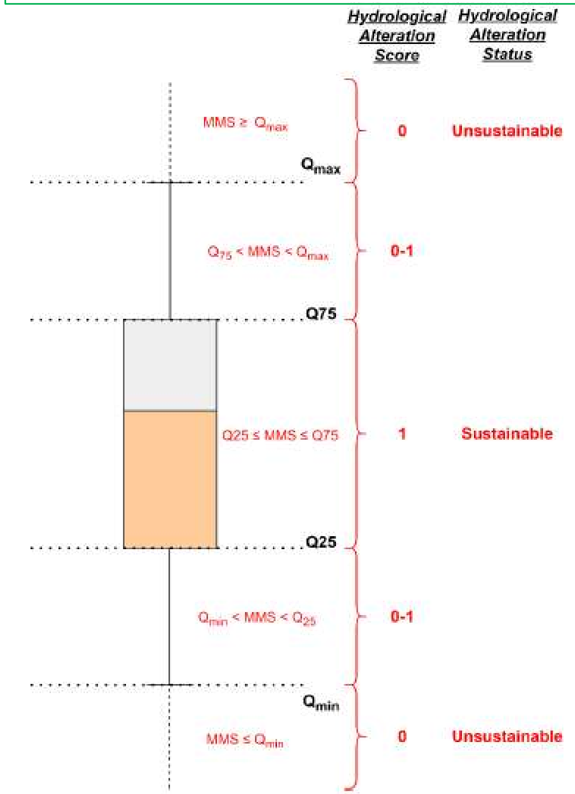


Figure 11. Schematic Representation of Status Assessments (Özcan Z. , 2023)

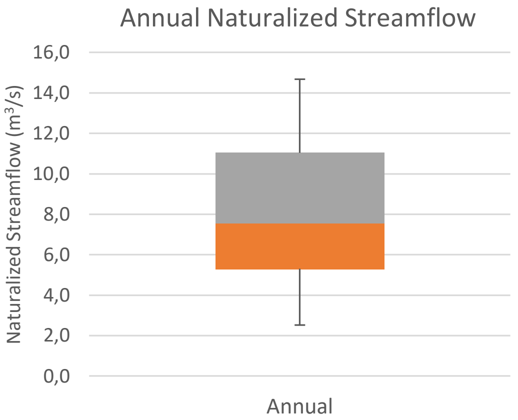


Figure 12. Naturalized Streamflow at Flow Monitoring Station No. E12A051 - Annual Average

If $5.3<Q<11$ m³/s

Sustainable

Table 5. Calculated Water Remaining in the Surface Water for Each Alternatives

Alternative	Flow rate (m³/s)	Alternative	Flow rate (m³/s)
S0-B	4.06	SR-R27	6.69
SR	7.14	SR-R28	6.69
SR-R3	6.51	SR-R29	6.83
SR-R4	6.72	SR-R30	6.66
SR-R5	6.51	SR-R31	6.43
SR-R6	6.91	SR-R32	6.60
SR-R7	6.83	SR-R33	6.71
SR-R8	6.57	SR-R34	6.68
SR-R9	6.64	SR-R35	6.42
SR-R10	6.70	SR-R36	6.66
SR-R11	6.44	SR-R37	6.71
SR-R12	6.71	SR-R38	6.53
SR-R13	6.70	SR-R39	6.66
SR-R14	6.75	SR-R40	6.73
SR-R15	6.62	SR-R41	6.57
SR-R16	6.75	SR-R42	6.70
SR-R17	6.71	SR-R43	6.70
SR-R18	6.60	SR-R44	6.53
SR-R19	6.67	SR-R45	6.85
SR-R20	6.70	SR-R46	6.65
SR-R21	6.72	SR-R47	6.61
SR-R22	6.42	SR-R48	6.51
SR-R23	6.64	SR-R49	6.86
SR-R24	6.68	SR-R50	6.88
SR-R25	6.35	SR-R51	6.74
SR-R26	6.81	SR-R52	6.68

CONCLUSION

Conclusion

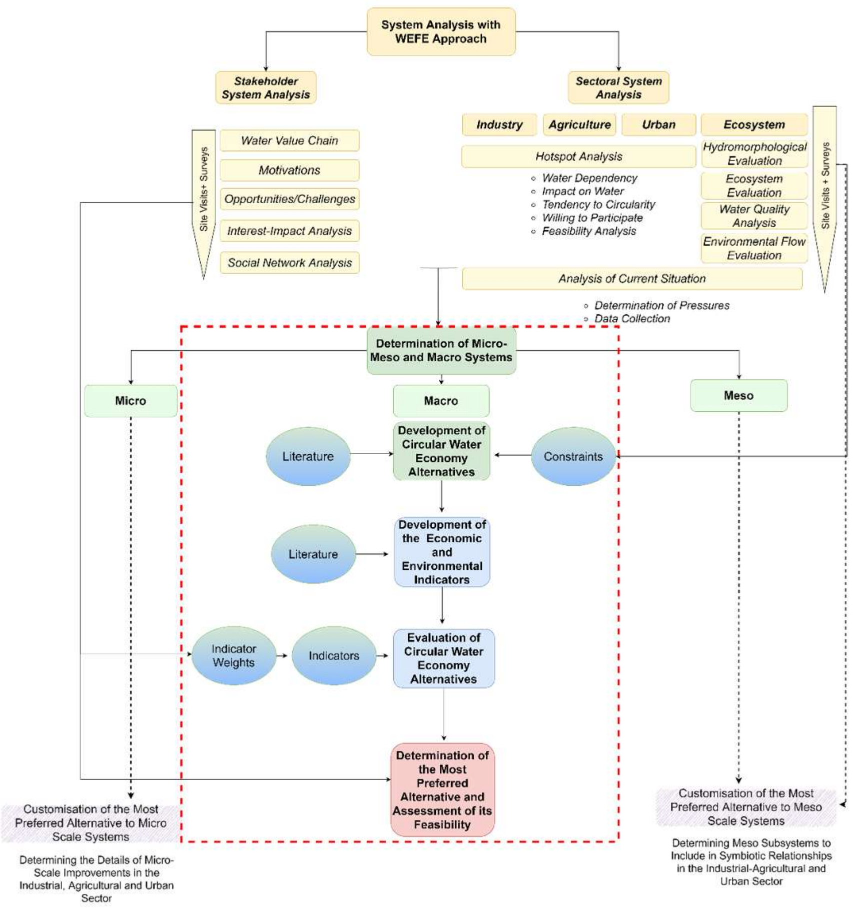


Figure 13. Suggested Framework for the evaluation of CE Alternatives with MCDM

The most preferred alternative by using suggested framework:

•Sending 7% of the wastewater from domestic wastewater treatment (WWTP) in Eskişehir to the Organized Industrial Zone (OIZ),

•Sending 4% of the wastewater from the domestic WWTP in Kütahya to the OIZ,

•Approximately 70% of the wastewater being reused within the OIZs,

•Dispatching treated wastewater to agricultural sectors in Eskişehir, where farmers draw more from surface water, and in Kütahya, where they draw from groundwater.

•Sending 2% of wastewater from domestic wastewater treatment to parks in Eskişehir while not dispatching any to Kütahya.

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&

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THANK YOU

REFERENCES

Al Haddid, O. N. (2021). The Challenges of Fulfilling SDG 6 for Cleaner Water and Sanitation, from a Multi-Stakeholder Perspective: A Case Study of Water Sustainability in the Jordanian -Mining Industry . *A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy* .

Alp, E., Yetiş, Ü., Gündüz, O., Aydınalp Köksal, M., Uzal, N., Güre, P. D., . . . Özertan, G. (2024). *Sürdürülebilir Su Yönetimi İçin Yeni Bir Yaklaşım: Su-Enerji-Gıda-Ekosistem Bağı Çerçevesine Döngüsel Ekonomi Yaklaşımının Entegrasyonu.*

Alsalem, M. A., Zaidan, A. A., Zaidan, B. B., Hashim, M., Albahri, O. S., Albahri, A. S., . . . Mohammed, K. I. (2018). Systematic Review of an Automated Multiclass Detection and Classification System for Acute Leukaemia in Terms of Evaluation and Benchmarking, Open Challenges, Issues and Methodological Aspects. *Journal of Medical Systems*.

An, V., Maarten, C., & Veronique, V. H. (2005). *Indicators for a Circular Economy* . Department of Economy Science & Innovation.

Arif, M., Suseno, J. E., & Isnanto, R. R. (2020). Multi-Criteria Decision Making with the VIKOR and SMARTER Methods for Optimal Seller Selection from Several E-Marketplaces. *ICENIS 2020.* EDP Sciences. https://doi.org/10.1051/e3sconf/202020214002

Arthington , A. H., Bhaduri, A., Bunn, S. E., Jackson, S. E., Tharme, R. E., Tickner, D., . . . Ward, S. (2018). The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018). *Frontiers in Environmental Science*. https://doi.org/10.3389/fenvs.2018.00045

Avdiushchenko, A., & Zajaç, P. (2019, 6). Circular economy indicators as a supporting tool for european regional development policies. *Sustainability (Switzerland), 11*(11).

Boix, M., Montastruc, L., Pibouleau, L., Azzaro-Pantel, C., & Domenech, S. (2011). Industrial water management by multiobjective optimization: from individual to collective solution through eco-industrial parks. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2011.09.011

Calzolari, T., Genovese, A., & Brint, A. (2021). Circular Economy indicators for supply chains: A systematic literature review. *Environmental and Sustainability Indicators*. https://doi.org/10.1016/j.indic.2021.100160

Carissimo, C., & Korecki, M. (2024). Limits of Optimization. *Minds and Machines*.

Carvalho, L., Mackay, B. E., Cardoso, A. C., Baattrup-Pedersen, A., Birk, S., Blackstock, K. L., . . . Solheim, A. L. (2019). Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive. *Science of the Total Environment*. https://doi.org/10.1016/j.scitotenv.2018.12.255

Damodaran, A. (2024, 1 5). *Country Default Spreads and Risk Premiums*. Retrieved from https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html

de Dios, L. G., Boix, M., Sauvage, S., Touche, I., Cakir, R., Montastruc, L., & Perez, J. M. (2018). Multiobjective optimization of eco-industrial parks:evaluation of environmental impacts at the watershed scale. *Proceedings of the 28th European Symposium on Computer Aided Process Engineering*. Graz, Austria. https://doi.org/10.1016/B978-0-444-64235-6.50014-0

Demirtaş Organized Industrial Zone Directorate. (2024, July 5). *Hizmet Fiyatları*. Retrieved from https://www.dosab.org.tr/Detay/64/Hizmet-Fiyatlari

Devi, G. K., Ganasri, B. P., & Dwarakish, G. S. (2015). A Review on Hydrological Models. *Aquatic Procedia*. https://doi.org/10.1016/j.aqpro.2015.02.126

Dominguez, S., Laso, J., Margallo, M., Aldaco, R., Rivero, M. J., Irabien, Á., & Ortiz, I. (2017). LCA of greywater management within a water circular economy restorative thinking framework. *Science of the Total Environment*. https://doi.org/10.1016/j.scitotenv.2017.10.122

DSİ. (2016). *Sakarya Havzası Master Planı Halk Sulamaları Nihai Raporu.*

DSİ. (2017, January). *Porsuk Alt Havzası Master Plan Nihai Raporu.*

DSİ. (2017). *Sakarya Havzası Master Plan Nihai Raporu.*

Elsadek, E., Noureldin, M., Shaltout, F., & Balah, A. (2023). WEAP analysis for enhancing water resource sustainability in Egypt: a dynamic modeling approach for long-term planning and management. *HBRC Journal*. https://doi.org/10.1080/16874048.2023.2260602

Eskişehir Metropolitan Municipality. (2021). *Eskişehir 2020 İstatistikleri.*

Eskişehir Water and Sewerage Administration. (2021). *ESKİ Faaliyet Raporu.*

EUR 10 Years IRS Interest Rate Swap (EURIRS10Y=). (2024, 6 14). Retrieved from investing.com: https://tr.investing.com/rates-bonds/eur-10-years-irs-interest-rate-swap-streaming-chart

European Commission. (2016). *EU Resource Efficiency Scoreboard 2015 Environment.* Retrieved from www.europa.eu

European Commission. (2024, February 28). *Water Framework Directive*. Retrieved from Europe's Freshwater: https://water.europa.eu/freshwater/europe-freshwater/water-framework-directive

REFERENCES

European Council. (2024, June 17). European Green Deal. Retrieved from https://www.consilium.europa.eu/en/policies/green-deal/

European Environment Agency. (2021, November 18). Ecological status of surface waters in Europe. Retrieved from https://www.eea.europa.eu/en/analysis/indicators/ecological-status-of-surface-waters

European Investment Bank. (2020). The EIB Circular Economy Guide Supporting the circular transition. European Investment Bank.

European Parliament. (2023, May 24). Retrieved from Circular economy: definition, importance and benefits: https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits

Farmer Registration System. (2022). 2019-2021 Eskişehir ve Kütahya Bitkisel Tarım Verileri.

Gebre, S. L., Cattrysse, D., & Orshoven, J. V. (2021). Multi-Criteria Decision-Making Methods to Address Water Allocation Problems: A Systematic Review. Water.

General Directorate of Kocaeli Water and Sewerage Administration. (2024, August). Su Fiyatları. Retrieved from https://www.isu.gov.tr/sufiyatlari/

Geng, Y., Fu, J., Sarkis, J., & Xue, B. (2012, 3). Towards a national circular economy indicator system in China: An evaluation and critical analysis. Journal of Cleaner Production, 23(1), 216-224.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2015.09.007

Grup Dizayn. (n.d.). Ürünler. Retrieved from PPRC BORULAR VE EK PARÇALARI: https://www.dizayngrup.com/pprc-borular-ve-ek-parcalari

Haloui, D., Oufaska, K., Oudani, M., & El Yassini, K. (2023). A multi-criteria decision-making approach for the sustainable location of urban farms: Towards Farming 4.0. 2023 9th International Conference on Control, Decision and Information Technologies. Rome,Italy. https://doi.org/10.1109/CODIT58514.2023.10284336

Harris, S., Martin, M., & Diener, D. (2021). Circularity for circularity's sake? Scoping review of assessment methods for environmental performance in the circular economy. Sustainable Production and Consumption, 26, 172-186.

Heshmati, A. (2017). A review of the circular economy and its implementation. Int. J. Green Economics, 11(3/4).

Holger, H. (2011). Understanding the Nexus Background Paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute.

Huo, J., & Peng, C. (2023). Depletion of natural resources and environmental quality: Prospects of energy use, energy imports, and economic growth hindrances. Resources Policy. https://doi.org/10.1016/j.resourpol.2023.104049

Kato, S., & Kansha, Y. (2024). Comprehensive review of industrial wastewater treatment techniques. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-024-34584-0

Khan, M., & Akhtar, N. (2020). Indicators for Circular Economy Downstream value chain mapping of Shipbreaking View project Helping Smallholder Farmers Adapt to Climate Change View project 6 Indicators for Circular Economy Indicators for Circular Economy Learning objectives. Retrieved from https://www.researchgate.net/publication/344121488

Kim, J. H., & Ahn, B. S. (2019). Extended VIKOR method using incomplete criteria weights. Expert Systems With Applications. https://doi.org/doi.org/10.1016/j.eswa.2019.02.019

Koska, A., & Erdem, M. B. (2023). Performance Analysis of ManufacturingWaste Using SWARA. Sustainability.

Kütahya Municipality. (2022). Su ve Kanalizasyon Müdürlüğü Faaliyet Raporu.

Liang, W.-z., Zhao, G.-y., & Hong, C.-s. (2018). Performance assessment of circular economy for phosphorus chemical. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2018.06.147

Mahmood, R., Jia, S., Lv, A., & Naeem, S. (2023). Environmental flow assessment, evaluation,and suggestions for dying riverine ecosystem of the transboundary Amudarya River, Central Asia. Ecological Indicators. https://doi.org/10.1016/j.ecolind.2023.111419

Mannan, M., & Al-Ghamdi, S. G. (2022). Complementing circular economy with life cycle assessment: Deeper understanding of economic, social, and environmental sustainability. In Circular Economy and Sustainability.

Mbavarira, T. M., & Grimm, C. (2021). A Systemic View on Circular Economy in theWater Industry: Learnings from a Belgian and Dutch Case. Sustainability. https://doi.org/10.3390/su13063313

Minguez, R., Gardoki, O. A., Lizundia, E., & Camara, E. S. (2021). Fostering Education for Circular Economy through Life Cycle Thinking.

Ministry of Environment, Urbanization and Climate Change. (2023). 2023 Yılı İnşaat ve Tesisat Birim Fiyatları.

REFERENCES

Moradi, N. (2023). Multi-Criteria Evaluation and Ranking of Circular Economy Water Management Alternatives for Porsuk Basin. A Thesis Submitted to the Graduate School of Natural And Applied Sciences of Middle East Technical University.

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G., Alaerts, L., Van Acker, K., . . . Dewulf, J. (2019, 7). Circular economy indicators: What do they measure? Resources, Conservation and Recycling, 146, 452-461.

Morseletto, P. (2019). Targets for a circular economy. Resources, Conservation & Recycling. https://doi.org/10.1016/j.resconrec.2019.104553

Morseletto, P., Mooren, C. E., & Munaretto, S. (2022). Circular Economy of Water: Definition, Strategies and Challenges. Circular Economy and Sustainability. https://doi.org/10.1007/s43615-022-00165-x

Nika, C. E., Vasilaki, V., Expósito, A., & Katsou, E. (2020). Water Cycle and Circular Economy: Developing a Circularity Assessment Framework for Complex Water Systems. Water Research. https://doi.org/10.1016/j.watres.2020.116423

Özcan, C. (2021). Assessment of the Hydrological Alterations and Environmental Flows in Sakarya Watershed, Turkey. A Thesis Submitted to the Graduate School of Natural And Applied Sciences of Middle East Technical University.

Özcan, Z. (2023). A Holistic Framework for Evaluating the Sustainability of the Water-Energy-Food-Ecosystem Nexus under Multiple Socioeconomic and Climate Change Conditions. A Thesis Submitted to the Graduate School of Natural and Applied Sciences of Middle East Technical University.

Pacurariu, R., Vatca, S., Lakatos, E., Bacali, L., & Vlad, M. (2021, 8). A critical review of EU key indicators for the transition to the circular economy. International Journal of Environmental Research and Public Health, 18(16).

Palafox-Alcantar, P. G., Hunt, D. V., & Rogers, C. D. (2020). A Hybrid Methodology to Study Stakeholder Cooperation in Circular Economy Waste Management of Cities. Energies. https://doi.org/10.3390/en13071845

Poponi, S., Arcese, G., Pacchera, F., & Martucci, O. (2021). Evaluating the transition to the circular economy in the agri-food sector: Selection of indicators. Resources, Conservation & Recycling. https://doi.org/10.1016/j.resconrec.2021.105916

Prasad, M. N., Smol, M., & Freitas, H. (2023). Chapter 1 - Achieving sustainable development goals via green deal strategies. In Sustainable and Circular Management of Resources and Waste Towards a Green Deal. Elseiver.

Ramírez-Agudelo, N. A., Pablo, J., & Roca, E. (2021). Exploring alternative practices in urban water management through the lens of circular economy–A case study in the Barcelona metropolitan area. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2021.129565

Rebuplic of Türkiye, Ministry of Environment, Urbanisation and Climate Change. (2014, June 17). Bakanlık Atıksu Arıtma Tesislerinin Enerji Giderlerinin %50'sini Karşılıyor. Retrieved from https://csb.gov.tr/bakanlik-atiksu-aritma-tesislerinin-enerji-giderlerinin-50-sini-karsiliyor-bakanlik-faaliyetleri-946

Reike, D., Vermeulen, W. J., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. Resources, Conservation & Recycling. https://doi.org/10.1016/j.resconrec.2017.08.027

Republic of Türkiye. (2004, December 31). Su Kirliliği Kontrolü Yönetmeliği. Retrieved from Mevzuat Bilgi Sistemi: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=7221&MevzuatTur=7&MevzuatTertip=5

Republic of Türkiye. (2010, March 20). Atıksu Arıtma Tesisleri Teknik Usuller Tebliği. Retrieved from Mevzuat Bilgi Sistemi: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=13873&MevzuatTur=9&MevzuatTertip=5

Republic of Türkiye. (2023, November 11). Mevzuat Bilgi Sistemi. Retrieved from Atıksu Arıtma Tesisi Enerji Teşviki Yönetmeliği: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=40411&MevzuatTur=7&MevzuatTertip=5

Republic of Türkiye- Ministry of Environment, Urbanisation and Climate Change. (n.d.). Resmi İstatistikler. Retrieved from İllere Ait Mevsim Normalleri (1991-2020): https://www.mgm.gov.tr/Veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=ESKISEHIR

Republic of Türkiye- Ministry of Environment, Urbanisation and Climate Change. (n.d.). Resmi İstatistikler. Retrieved from İllere Ait Mevsim Normalleri (1991-2020): https://www.mgm.gov.tr/Veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=KUTAHYA

Republic of Türkiye Ministry of Foreign Affairs. (2024). Retrieved from European Green Deal: https://www.ab.gov.tr/european-green-deal_53729_en.html

Republic of Türkiye, Ministry of Environment, Urbanization and Climate Change. (2021). Kütahya İli Çevre Durum Raporu 2020.

Rincón-Moreno, J., Ormazábal, M., Álvarez, M., & Jaca, C. (2021, 1). Advancing circular economy performance indicators and their application in Spanish companies. Journal of Cleaner Production, 279.

Rossi, E., Bertassini, A. C., dos Santos Ferreira, C., Neves do Amaral, W. A., & Ometto, A. R. (2019). Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electroelectronic cases. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2019.119137

Rönnlund, I., Reuter, M., Horn, S., Aho, J., Aho, M., Päällysaho, M., . . . Pursula, T. (2016, 10). Eco-efficiency indicator framework implemented in the metallurgical industry: part 1—a comprehensive view and benchmark. International Journal of Life Cycle Assessment, 21(10), 1473-1500.

Sayadi, M. K., & Shahanaghi, K. (2008). Extension of VIKOR method for decision making problem. Applied Mathematical Modelling. https://doi.org/10.1016/j.apm.2008.06.002

REFERENCES

Schlemm, A., Mulligan , M., Tang, T., Agramont, A., Namugize, J., Malambala, E., & Griensven, A. (2024). Developing meaningful water-energy-food-environment (WEFE) nexus indicators with stakeholders: An Upper White Nile case study. Science of The Total Environment. https://doi.org/10.1016/j.scitotenv.2024.172839

Schmeer, K. (2000). Stakeholder Analysis Guidelines.

Sempa Pump. (2022). 2022 Fiyat Kıtapçığı.

Shammas, N. K., & Wang, L. K. (2011). Water Supply and Wastewater Removal.

Sillanpaa, M., & Ncibi, C. (2004). The Circular Economy Case Studies about the Transition from the Linear Economy. 221-229.

Silvestri, L., Forcina, A., Di Bona, G., & Silvestri, C. (2021). Circular economy strategy of reusing olive mill wastewater in the ceramic industry: How the plant location can benefit environmental and economic performance. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2021.129388

Silvestri, L., Silvestri, C., Forcina, A., & De Luca, C. (2022, 1). A review of energy-based indicators for assessing sustainability and circular economy in the agri-food production. Procedia Computer Science, 200, 1756-1765.

Smol, M., & Koneczna, R. (2021). Economic Indicators in Water and Wastewater Sector Contributing to a Circular Economy (CE). Resources. https://doi.org/doi.org/10.3390/resources10120129

Smol, M., Adam, C., & Preisner, M. (2020). Circular economy model framework in the European water. Journal of Material Cycles and Waste Management. https://doi.org/10.1007/s10163-019-00960-z

Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: Moving from rhetoric to implementation. Journal of Cleaner Production, 42(July 2019), 215-227.

Sun, L., Niu, D., Yu, M., Li, M., Yang, X., & Ji, Z. (2021). Integrated assessment of the sustainable water-energy-food nexus in China: Case studies on multi-regional sustainability and multi-sectoral synergy. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2021.130235

Swiniarski, S. (2022, 2 10). .uniform(). Retrieved from Code Academy: https://www.codecademy.com/resources/docs/python/random-module/uniform

The Engineering ToolBox. (2004). Retrieved from Fluid Flow Friction Loss- Hazen Williams Coefficients: https://www.engineeringtoolbox.com/hazen-williams-coefficients-d_798.html

Turkiye General Directorate of Mapping. (2021). İl ve İlçe Yüz Ölçümleri.

TURKSTAT. (2020). Belediye Atıksu İstatistikleri.

TURKSTAT. (2020). Belediye Su İstatistikleri.

TURKSTAT. (2023, 7 30). İstatistik Veri Portalı. Retrieved from Yıllara göre il nüfusları, 2023-2030: https://data.tuik.gov.tr/Kategori/GetKategori?p=Nufus-ve-Demografi-109

UNESCO, European Commission, IWA. (2021). Implementing the Water–Energy–Food–Ecosystems Nexus and Achieving the Sustainable Development Goals.

United Nations. (n.d.). Retrieved from Transforming our world: the 2030 Agenda for Sustainable Development: https://sdgs.un.org/2030agenda

United Nations. (2007). Indicators of Sustainable Development: Guidelines and Methodologies. Economic & Social Affairs.

United Nations. (2023). Progress towards the Sustainable Development Goals: towards a rescue plan for people and planet. Report of the Secretary-General (special edition).

United Nations. (2024). Progress towards the Sustainable Development Goals Report of the Secretary-General.

United Nations. (n.d.). History. Retrieved from Department of Economic and Social Affairs- Sustainable Development: https://sdgs.un.org/goals

United Nations. (n.d.). Working with the Water-Energy-Food-Ecosystems (WEFE) nexus. UNEP Copenhagen Climate Centre.

REFERENCES

Valenzuela-Venegas, G., Salgado, J. C., & Diaz-Alvarado, F. A. (2016). Sustainability indicators for the assessment of eco-industrial parks:classification and criteria for selection. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2016.05.113

van Vliet, L., Levidow, L., & Skenhall, S. A. (2013). Meso-level eco-efficiency indicators to assess technologies and their uptake in water use sectors.

Vanhamäki, S., Medkova, K., Malamakis, A., Kontogianni, S., Marisova, E., Dellago, D. H., & Moussiopoulos, N. (2019). Bio-based circular economy in European national and regional strategies. International Journal of Sustainable Development and Planning. https://doi.org/10.2495/SDP-V14-N1-31-43

Velasco-Muñoz, J., Mendoza, J., Aznar-Sánchez, J., & Gallego-Schmid, A. (2021, 7). Circular economy implementation in the agricultural sector: Definition, strategies and indicators. Resources, Conservation and Recycling, 170.

Vermeulen, W. J., & Witjes, S. (2019). Circular Economy 3.0 - Solving confusion around new conceptions of circularity by synthesising and re-organising the 3R's concept into a 10R hierarchy.

Viles, E., Santos, J., Arévalo, T. F., Tanco, M., & Kalemkerian, F. (2020). A new mindset for circular economy strategies: Case studies of circularity in the use of water. Sustainability (Switzerland), 12(22), 1-12.

Vitor dos Santos Gonçalves, P., & Campos, L. M. (2022). A systemic review for measuring circular economy with multi criteria. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-022-18580-w

Water Environment Federation. (2023). Circular Water Economy. Retrieved from Wat is a 'Circular Water Economy'?: https://www.wef.org/topics/hot-topics/circular-water-economy/#:~:text=What%20Is%20A%20'Circular%20Water,people%2C%20nature%2C%20and%20businesses.

World Health Organization. (2024). Retrieved from The Global Health Observatory/Themes: https://www.who.int/data/gho/data/themes/world-health-statistics#tab=tab_1

Xavier, L. H., Ottoni, M., & Abreu, L. P. (2023). A comprehensive review of urban mining and the value recovery from e-waste materials. Resources, Conservation and Recycling. https://doi.org/10.1016/j.resconrec.2022.106840

Zafer Development Agency. (n.d.). Kütahya Yerel Ekonomik Gelişme Programı (2017-2019).

Zhang, Z., He, Y., Chen, X., & Tan, Q. (2023). Improvement of WEAP model considering regional and industrial water distribution priority and its application. Journal of Hydrology: Regional Studies. https://doi.org/10.1016/j.ejrh.2023.101414

Zhao, H., Zhao, H., & Guo, S. (2016). Evaluating the comprehensive benefit of eco-industrial parks by. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2016.11.041