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Vpliv oskrbe z energijo na sonaravno uravnotežen razvoj Slovenije v obdobju do leta 2020

The Influence of Energy Supply on the Sustainable Development of Slovenia up to year 2020

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Spoznanja o pretiranem črpanju neobnovljivih naravnih virov in neenakost kakovosti življenja ljudi je privedlo do spoznanja po nujnih omejitvah energijskih in snovnih tokov, ki jih ustvarja človeštvo. Torej k ravnanju, ki ga imenujemo sonaravno uravnotežen razvoj[1]. Tudi Slovenija se je zavezala k takemu ravnanju. Stopnjo približevanje željenemu cilju pa lahko ugotavljamo le, če uporabimo metodo s katero postane razvoj merljiv. V zadnjih letih se je kot ena od metod uveljavila metoda ekoloških sledi. V delu opisujemo metodo in jo prvič uporabljamo v Sloveniji. Ugotovimo, da je v sedanjem trenutku za Slovenijo značilen netrajnostni razvoj, saj ekološke sledi povprečnega prebivalca Slovenije presegajo lokalno (v Sloveniji) in globalno (na planetu) razpoložljivo bioproduktivno površino. Ugotovimo pomen oskrbe prebivalcev Slovenije z energijo in z upoštevanjem napovedane rabe energije, ki je ocenjena v najpomembnejših državnih razvojnih dokumentih in direktivah EU, napovemo spreminjanje ekoloških sledi v odbobju do leta 2020.

(Ključne besede: Slovenija, razvoj uravnotežen, oskrba z energijo, sledi ekološke)

Knowing that humans overexaggerated extracting nonrenewable natural sources which caused nonequal quality of life lead to the awareness that energy and mass flows generated by mankind should be decreased drastically. Only than the sustainable development on the planet could be achieved. Slovenia also expresses commitment to the sustainable development. The grade approaching to the final goal can be measured only by an appropriate method. In the last years the environmental footprints become wide used. In the paper the method is described and first time used for calculation of environmental footprints of Slovenian inhabitance. It was found out that current development is non sustainable because environmental footprints of Slovenian's are greater than local and global bio-productive space. The influence of the current energy use on the environmental footprints is analyzed and prediction of the future environmental footprints caused by the use of energy predicted in most important national strategic documents and EU Directives up to year 2020 are presented.

(Keywords: Slovenia, sustainable development, energy supply, ecological footprint)

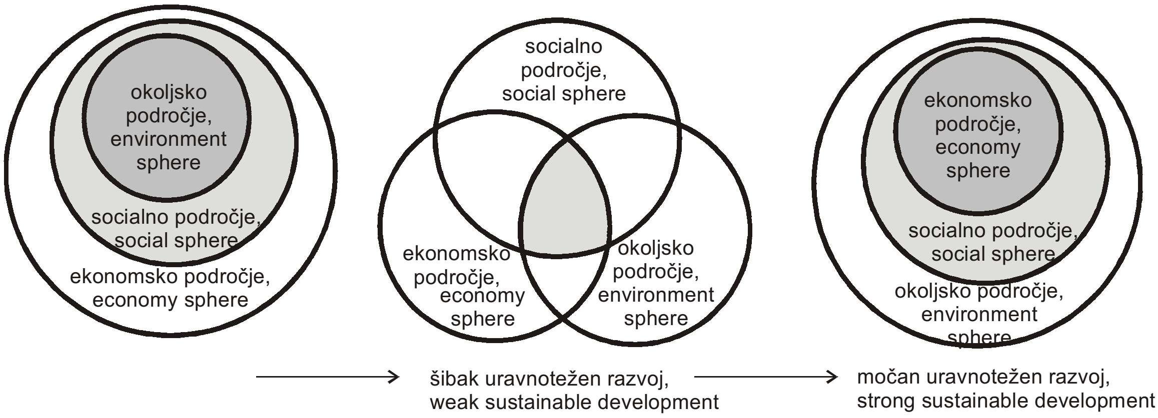
0 UVOD

Za razvoj zadnjih dvesto let je značilna neprestana gospodarska rast. Povečalo se je število prebivalstva, še bolj pa količina in kakovost proizvodnje. To je obdobje, za katero je značilna vera v možnost nezadržne rasti, ki ji lahko postavlja meje edino človek sam. Leta 1987 je v okviru Svetovne komisije za okolje in razvoj potekala konferenca, ki je v skupnem poročilu z naslovom "Naša skupna prihodnost" napovedala največje grožnje človeštvu

0 INTRODUCTION

The history of the past two hundred years has been characterised by continuous economic growth. The quantity and quality of production has increased even more than the population. This has been an era characterised by a faith in the possibility of ever-increasing growth, which only mankind can control. In 1987 there was a conference organised under the umbrella of the World Commission on Environment and Development, which defined in the

[1]Opomba: v slovenskem okolju je izraz "sustainable development" prevajan različno – trajnostni razvoj, sonaravni, vzdržni, samovzdržni; v našem delu uporabljamo definicijo Sveta za varstvo okolja Republike Slovenije "sonaravno uravnotežen razvoj".



Sl. 1. *Proces preoblikovanja vrednot v procesu približevanja sonaravno uravnoteženemu razvoju ([1] in [2])*
Fig. 1. *The process of value change within the process of approximation to sustainable development ([1] and [2])*

v prihodnosti - množično revščino, povečevanje števila prebivalstva, spreminjanje podnebja, zmanjšanje kakovosti okolja. Sklepi konference pomenijo temelje dejavnosti, ki jih dandanes s skupnim izrazom imenujemo sonaravno uravnotežen razvoj. Tedaj so oblikovali tudi relativno suhoparno definicijo tega postopka, ki se glasi: "sonaravno uravnotežen razvoj zadovoljuje potrebe sedanjih generacij, ne da bi pri tem zmanjševali možnosti prihodnjih generacij pri zadovoljevanju njihovih lastnih potreb". Reševanje teh problemov zahteva sočasno opazovanje treh področij družbe - ekonomskega, socialnega in okoljskega. Interesi in zahteve posameznih področij se med seboj prepletajo. Ko opazujemo postopek ocenjevanja vrednot v časovni lestvici, lahko sledimo prevladi ekonomskega področja, prek enakopravnosti ekonomskega, socialnega in ekonomskega področja (šibak sonaravno trajnostni razvoj) do prevlade okoljskega področja (močan sonaravno trajnostni razvoj). Ta postopek h končnemu cilju - sonaravno uravnoteženemu razvoju prikazuje slika 1.

Zavezanost približevanju sonaravno uravnoteženemu razvoju je tako mednarodna skupnost kakor Slovenija izrazila v številnih mednarodnih deklaracijah in razvojnih listinah. Hkrati z razvojnimi strategijami so bile razvite tudi metode, s katerimi ocenjujemo približevanje končnemu cilju. V zadnjih letih med njimi izstopa metoda okoljskih sledi.

1 MERJENJA SONARAVNO URAVNOTEŽENEGA RAZVOJA Z OKOLJSKIMI SLEDMI

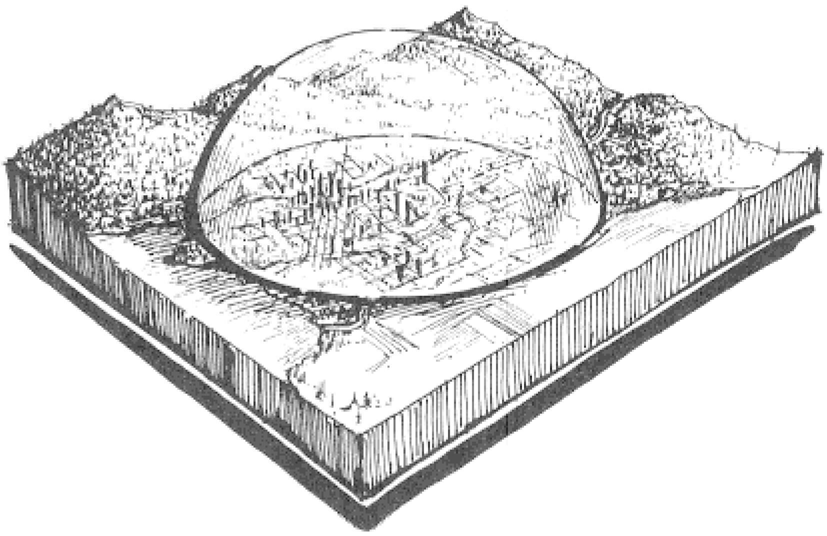
V zadnjem desetletju razvita teorija merjenja sonaravno uravnoteženega razvoja z okoljskimi sledmi temelji na podlagi velikosti prostora, ki si ga »prisvoji«, za zadovoljevanje lastnih potreb, nek sistem (človeštvo, država, lokalna skupnost, posameznik). Velikost prostora merimo s površinskimi enotami, ki ponazarjajo

frame of a joint report under the title "Our Common Future", the biggest threats to future humanity: mass poverty, population increase, change of climate and environmental degradation. The conference's conclusions are the background to activities that are nowadays referred to as sustainable development. The definition of sustainable development that was formed at this conference is as follows: "Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs". Solving such problems requires the constant monitoring of three areas in society: economic, social and environmental. There is, of course, an interplay of interests and requirements for these individual areas. When the process of value evaluation is observed in relation to time scale, one may note either a predominance of the economic area or an equivalence between the economic, the social and the environmental areas (weak sustainable development), or a dominance of the environmental area (strong sustainable development). The process to achieve the final goal of sustainable development is presented in Figure 1.

The international community – including Slovenia – has expressed its commitment to sustainable development in numerous international declarations and developmental documents. The methods necessary to measure the degrees of success in achieving the final goals were developed in parallel with the developmental strategies. In recent times the environmental footprint method has gained more prominence.

1 THE ENVIRONMENTAL FOOTPRINT: A TOOL FOR MEASURING SUSTAINABLE DEVELOPMENT

The theory of measuring sustainable development with environmental footprints was developed during the past decade. The theory is based on the amount of environmental space occupied by a particular system – human race, country, local community, individual – in order for that system to provide for its own needs. The amount of space is measured in units of area, which are



Sl. 2. *Shematski prikaz okolja, na katerem neki sistem zadovoljuje svoje življenjske in razvojne potrebe – kolikostno in kakovostno ocenjena površina tega prostora ponazarja okoljske sledi sistema [1]*
Fig. 2. *Schematic representation of an environmental space where a particular system covers its living and developmental needs – the quantitatively and qualitatively appraised area of this space indicates the environmental footprint of a system [1]*

okoljske sledi (ES). Z njimi torej merimo kolikost in kakovost okoljskega prostora, ki je nujno potreben za stalno proizvodnjo in oskrbo z viri in asimilacijo odpadkov (v vseh pojavnih oblikah), ki jih proizvede opazovan sistem. Metoda okoljskih sledi torej temelji na oceni nosilne zmogljivosti okolja.

Metoda je bila razvita v okviru projekta Uravnotežena Evropa ([3] in [4]). Leta 1992 jo je kot metodo merjenja sonaravno uravnoteženega razvoja uveljavila skupina Prijatelji Zemlje na Nizozemskem. Od uvedbe se je metoda uveljavila v svetovnem merilu za presojo sistemov zelo različnih velikosti. Uveljavitev metode je posledica dveh izrazitih primerjalnih prednosti te metode:

– okoljske sledi so celostni kazalnik
– ker jih merimo s površinskimi enotami so nazorno predstavljive in izražene z absolutnimi vrednostmi, ter imajo neko končno planetarno vrednost

Velikost prostora, ki ga ima na voljo opazovani sistem znotraj svojih meja, imenujemo biološko proizvodna površina (BP). Sistem na tej površini zagotavlja potrebne vire in ponore energijskih in snovnih tokov, ki tečejo prek meja ali znotraj opazovanega sistema. Biološko proizvodne površine razdelimo v več vrst. Prikazuje jih preglednica 1. Dodamo jim tudi energijsko površino, ki je namišljena površina in določena bodisi kot:

– površina za biološko asimilacijo plinov, ki nastajajo pri sežigu fosilnih goriv in jih ovrednotimo s toplogrednim ekvivalentom CO_2,
– površina, na kateri bi prirastek lesne biomase

then expressed in terms of environmental footprints (EFs). Environmental footprints measure the quantity and the quality of an environmental space that is required to consistently produce and supply the resources and to assimilate the wastes (in all forms) generated by a given system. The method of environmental footprints is based on an appraisal of the environmental carrying capacity.

The method of environmental footprints has been developed within the Sustainable Europe project ([3] and [4]). It was established as a method of measuring sustainable development in 1992 by a group called Friends of the Earth – Netherlands. Since its establishment, the method has become accepted around the world as a method for appraising systems of various sizes. The wide acceptance of the method is mainly due to its two comparative advantages:

– environmental footprints are an integral indicator;
– since they are measured in area units, they are easily imagined, expressed in absolute values, and have some kind of final global value.

The amount of space that a given system has within its limits is its bio-productive space (BP). Within this space the system ensures all the necessary resources as well as the source/sinks of energy and material flows running across or within the limits of the given system. A bio-productive space can be classified into many categories. These categories are presented in Table 1, together with the energy space, which is fictitious and determined as one of the following:

– the space for the biological assimilation of gases resulting from burning fossil fuels measured by a greenhouse carbon-dioxide equivalent;
– the space where an increment of wood biomass

nadomestil fosilna goriva,

– površina, ki bi zadoščala za proizvodnjo biometanola, bioetanola in biodizla v količini, ki bi nadomestila fosilna goriva.

V našem prispevku bomo uporabili metodo asimilacije ekvivalenta toplogrednih plinov. Za različne vrste bioproizvodnih površin so značilne različne lastnosti. Zato fizično velikost posamezne vrste dogradimo s povprečno svetovno proizvodnostjo, ki jo imenujemo enakovredni faktor. Ebakovredne površine merimo v globalnih hektarih ([1], [4] do [6]). Rodovitnost in absorpcijska zmožnost različnih vrst površin se razlikuje tudi geografsko. Razlike med svetovnim povprečjem in značilnicami sistema, ki ga opazujemo, ovrednotimo s faktorjem pridelka. Ker si ljudje delimo planet z drugimi organizmi, del prostora ohranimo za njihov razvoj. Mnenja raziskovalcev o potrebni površini za ohranjanje biotske raznovrstnosti so različna – od 3,5 do 50% glede na celotno biološko proizvodni prostor. Najpogosteje ([2] in [5]) se upošteva vrednost 12%. Ta površina zmanjšuje površino prostora, ki jo za svoje potrebe lahko izkoriščajo ljudje. Ker je zadovoljevanje potreb neke populacije odvisno tudi od njenega števila, izračunamo delež celotne enakovredne bioproizvodne površine, ki pripada posamezniku v opazovanem sistemu. Prav tako okoljske sledi opazovanega sistema opredelimo glede na populacijo.

2 BIOLOŠKO PROIZVODNE POVRŠINE V SLOVENIJI

Slovenija, katere površina je 20.273 km^2, je imela v letu 2002 1.990.272 prebivalcev. Preglednica 1 navaja izračunano velikost biološko proizvodne površine na področju Slovenije. Površino Slovenije, ki jo zasedajo posamezne vrste biološko proizvodnih površin, povzamemo po uradnih statističnih virih [7] Enakovredni faktorji pomenijo svetovno povprečje ([3] in [4]), medtem ko je faktor pridelka lokalnega značaja. Faktorji pridelka za Slovenijo so določeni za leto 2002 ([7] do [9]) glede na količine pridelkov in svetovno povprečje. Splošno skupno biološko proizvodno površino v sistemu določimo z izrazom:

would replace fossil fuels;

– the space that would suffice for the production of bio-methanol, bio-ethanol and bio-diesel in an amount sufficient to replace fossil fuels.

In this paper the method of assimilating greenhouse-gas equivalents is used. Each bio-productive space is unique. Therefore, the amount of physically existing space for a particular category is adjusted for the world's average productivity, i.e., the equivalence factor. The equivalent areas of space are measured in global hectares ([1], [4] to [6]). The fertility and absorption capacity of various types of spaces vary geographically too. The difference between the world average and the characteristics of a given system is expressed with a yield factor. Since people share the planet with other species, some spaces have to be preserved for the development of these species. Researchers' opinions on the amount of space necessary to preserve biodiversity vary – from 3.5 to 50% of the entire bio-productive space. However, an value of 12% is generally accepted ([2] and [5]). This space reduces the amount of space that might otherwise be used by people to satisfy their needs. Because satisfying the needs of a particular population depends on the size of this population, a share of the equivalent bio-productive space appertaining to an individual in a given system is calculated. Similarly, the environmental footprints of a given system are defined in terms of a given population.

2 BIO-PRODUCTIVE SPACE IN SLOVENIA

Slovenia measures 20,273 km^2 and has a population of 1,990,272 (in 2002). Table 1 presents the calculated amount of bio-productive space in the region of Slovenia. The Slovenian space, composed of relevant bio-productive areas, is adopted from the official statistical source [7]. The equivalence factors represent the world average [3] and [4], while the yield factors are local. The yield factors for Slovenia for 2002 [7] to [9] are defined in terms of the harvest quantity and the world average. The total area of bio-productive space in a system is defined by the following equation:

$$BP = \sum_{j=1}^{5} A_j ef_j fp_j \qquad (1),$$

kjer so:

BP biološko proizvodna površina sistema (gha),
j vrsta biološko proizvodne površine (1),
ef enakovredni faktor posameznega tipa biološko proizvodne površine (gha/ha),
fp faktor pridelka posameznega tipa biološko proizvodne površine (1).

Ocena sonaravno uravnoteženega razvoja opazovanega sistema temelji na primerjavi razpoložljive biološko proizvodne površine in

where:

BP the bio-productive space of a system (gha);
j the type of bio-productive space (1);
ef the equivalence factor of the individual type of bio-productive space (gha/ha);
fp the yield factor of the individual type of bio-productive space (1).

An appraisal of the sustainable development of a given system is based on a comparison between the available bio-productive space and the deter-

Preglednica 1. *Velikost biološko proizvodnih površin v Sloveniji na prebivalca v letu 2002*
Table 1. *The amount of bio-productive space per capita in Slovenia in 2002*

Vrsta bioproizvodnih površin Type of bio-productive space	**indeks j index j**	**površina (ha/preb) space (ha/capita)**	**enakovredni faktor equivalence factor (gha/ha)**	**faktor pridelka yield factor (1)**	**globalni hektari (gha/preb) global hectares (gha/capita)**
kmetijske površine crop land	1	0,13	2,11	1,69	0,46
pašniki grazing land	2	0,22	0,47	3,60	0,37
gozdovi kot vir gradbenega lesa forests as a source of timber	3	0,63	1,35	2,42	2,06
sladko in slanovodna področja kot vir morske hrane fresh- and salt-water areas as a source of seafood	4	0,01	0,35	1,00	0,00
pozidane površine naselij, prometnih poti, infrastrukturne površine built-up areas for accommodation, transportation and infrastructure	5	0,004[1]	1,35	1,00	0,01
energijske površine, kot vir/ponor toplogrednih plinov s CO_2 ekvivalentom energy space, as source/sink of greenhouse gases expressed as a carbon-dioxide equivalent	6	-	1,00	-	-
skupaj total					**2,90**
potreben prostor za zagotavljanje biotske raznovrstnosti space required to ensure bio-diversity					**0,35**
preostanek difference					**2,55**

[1]Opomba: pri pozidanih površinah ocenjujemo delež zelenih površin kot 10%.
[1]Note: within the category named "built-up areas", green plots are estimated to cover 10% of the area.

ugotovljenih okoljskih sledi, ki jih povzroča njegova populacija. Razlika opredeljuje okoljski presežek ali primanjkljaj, značilen za opazovani sistem.

$$\Delta ED = BP - ES = BP - \left(ES_E + ES_H + ES_S + ES_G \right) \quad (2),$$

kjer so:
ΔED presežek ali primanjkljaj okoljskih sledi (gha/preb),
ES_E okoljske sledi, nastale pri oskrbi z energijo (gha/preb),
ES_E okoljske sledi, nastale pri proizvodnji in oskrbi s hrano (gha/preb),
ES_S okoljske sledi zaradi rabe snovi in ravnanja z odpadki (gha/preb),
ES_G okoljske sledi grajenega okolja (gha/preb).

Če je razlika določena zgolj glede na lastno biološko proizvodno površino opazovanega sistema, ocenjujemo lokalni sonaravno uravnotežen razvoj;

mined environmental footprints generated by its population. The difference gives the environmental surplus or deficit for a given system.

where:
ΔED environmental surplus or deficit (gha/capita);
ES_E environmental footprints resulting from the energy supply (gha/capita);
ES_E environmental footprints resulting from production and food supply (gha/capita);
ES_S environmental footprints resulting from material consumption and waste handling (gha/capita);
ES_G environmental footprints resulting from a built-up environment (gha/capita);

The difference determined on the basis of the bio-productive space of a given system gives an estimation of the local sustainable development; how-če okoljske sledi populacije v sistemu primerjamo s planetarno biološko proizvodno površino, ugotavljamo globalni sonaravno uravnotežen razvoj. Po podatkih ([1], [3] in [4]) je trenutna velikost planetarnih biološko proizvodnih površin 1,9 gha na prebivalca Zemlje. Torej lahko sklepamo, da biološko proizvodne površine v Sloveniji (pregl. 1) pomembno presegajo svetovno povprečje.

Kljub mednarodni uveljavljenosti metode okoljskih sledi smo ugotovili, da metoda v Sloveniji še ni bila uporabljena. Zato je namen tega prispevka tudi prenos metode v slovensko okolje ter določitev resničnega okoljskega presežka ali primanjkljaja v sedanjem trenutku.

3 METODOLOGIJA IZRAČUNA OKOLJSKIH SLEDI

Okoljske sledi določimo po dveh osnovnih metodah – celovito ali komponentno. Celostna metoda sledi bilanci energijskih in snovnih tokov na lupini in v notranjosti opazovanega sistema, pri komponentni metodi pa analiziramo dejansko rabo energije in snovi posameznika v opazovanem sistemu. Za statistično dobro vrednotene in z jasno mejo definirane sisteme praviloma, tako kakor v tem delu, uporabljamo celostno metodo. Pri obeh metodah z uvedbo utežnih faktorjev tokov energentov in snovi postanejo okoljske sledi primerljive z biološko proizvodnimi površinami. Slika 3 prikazuje energijske tokove, ki jih obravnavamo pri celoviti metodi izračuna energijskih okoljskih sledi.

Okoljske sledi, ki so posledica rabe energije, določimo z izrazom:

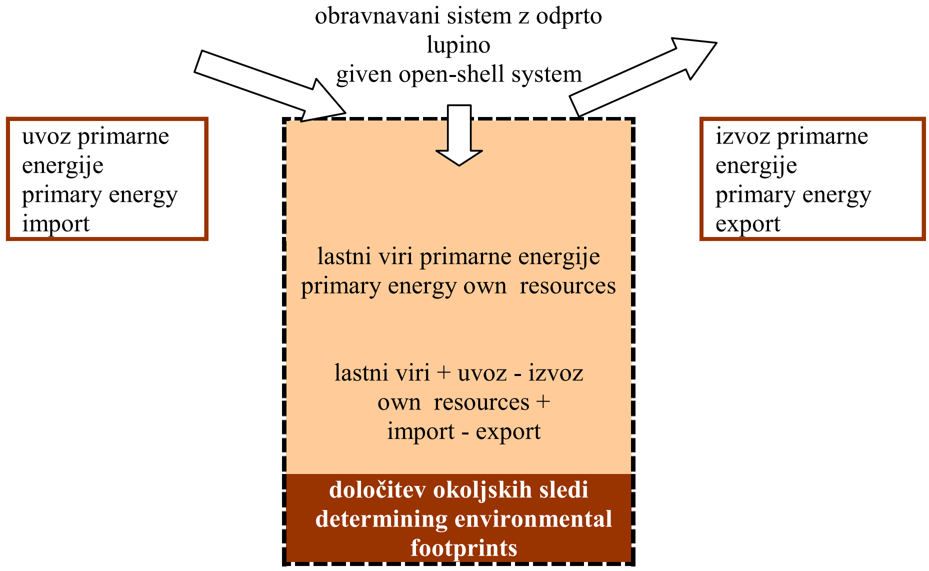
ever, when the environmental footprints of a population in a system are compared to the world's bio-productive space, then global sustainable development is estimated. According to the data available ([1], [3] and [4]), the current amount of planetary bio-productive space equals 1.9 gha per person. Therefore, it can be concluded that the bio-productive space in Slovenia (Table 1) significantly exceeds the world average.

Although the environmental footprints method has been internationally recognised, it has not been used in Slovenia yet. Therefore, the aim of this paper is to apply this method to the Slovenian environment and determine Slovenia's current, real environmental surplus or deficit.

3 METHODOLOGY FOR CALCULATING ENVIRONMENTAL FOOTPRINTS

Environmental footprints are determined with two basic methods: the integral method and the component method. The integral method follows the balance of the energy and material flows on the shell as well as inside a given system, while the component method aims at analysing the actual energy and material consumption of an individual in a given system. The integral method is used for statistically well-evaluated and clearly defined systems, such as those used in this article. With both methods, the environmental footprints become comparable with the bio-productive space by initiating a weighting factor for the energy and material flows. Figure 3 presents the energy flows used for calculating the energy footprints with the integral method.

Environmental footprints caused by energy consumption are determined with the following equation:



Sl. 3. *Shematski prikaz določitve okoljskih sledi, ki so posledica rabe energije nekega sistema s celostno metodo*

Fig. 3. *Schematic representation of the method for determining the environmental footprints caused by energy consumption in a system using the integral method*

$$ES_E = \sum_{m=1}^{n}\sum_{j=1}^{6}(k_{j,m}u_m + k_{j,m}v_m - k_{j,m}e_m) \quad (3),$$

kjer so:
ES_E energijske okoljske sledi (gha/ leto),
m vrsta energenta (1),
j vrsta biološko proizvodne površine (1),
u_m količina primarne energije, ki jo v sistem uvozimo z energentom m (GWh/leto),
v_m notranji vir primarne energije energenta m (GWh/leto),
e_m količina primarne energije, ki jo iz sistema izvozimo z energentom m (GWh/leto),
$k_{j,m}$ utežni faktor za j vrsto biološko proizvodne površine in energent m (gha/GWh).

Utežne faktorje energentov določimo glede na vgrajeno energijo v sisteme za spremembo energije ter emisije, ki nastajajo pri spremembi energije. Navajajo jih dela [1], [6] in [9].

Pri izračunu okoljskih sledi, ki so posledica proizvodnje hrane, porabe snovi in ravnanja z odpadki, se moramo pri celostni metodi dosledno izogibati dvojnemu štetju okoljskih sledi. Zato je treba paziti, da vgrajeno energijo upoštevamo samo pri snoveh, ki jih uvozimo, ter da pri okoljskih sledeh ne upoštevamo snovi, ki jih iz sistema izvozimo. Vgrajeno energijo v teh snoveh in energijo, ki je potrebna za prevoz do meje sistema, odštejemo od skupnih okoljskih sledi sistema:

where:
ES_E energy footprints (gha/year);
m type of energy product (1);
j type of bio-productive space (1);
u_m the amount of primary energy imported in a system by energy product m (GWh/year),
v_m internal source of primary energy of energy product m (GWh/year),
e_m the amount of primary energy exported from a system by energy product m (GWh/year),
$k_{j,m}$ weighting factor for j type of bio-productive space and energy product m (gha/GWh).

The weighting factors of the energy products are determined based on embodied energy in the systems used for energy conversion and based on emissions resulting from such energy conversion. They are cited in sources [1], [6] and [9].

When calculating the environmental footprints caused by food production, material consumption and waste handling using the integral method, double accounting of the environmental footprints should be consistently avoided. Therefore, one must pay attention and recognise embodied energy only in the materials being imported. Further, the materials that are exported from the system should not be taken into account when calculating the environmental footprints. The embodied energy in such materials and the energy needed for transport to the system border is subtracted from the total environmental footprints of the system:

$$ES_S = \sum_{i=1}^{n}\sum_{j=1}^{5}(k_{j,i}p_i + k_{j,i}u_i - k_{j,i}e_i) + \sum_{i=1}^{n}(k_{6,i}u_i - k_{6,i}e_i) + \sum_{i=1}^{n}(k_{6,h,i}s_{h_i}u_i - k_{6,h,i}s_{h_i}e_i) \quad (4),$$

kjer so:
ES_s okoljske sledi, ki so posledica rabe snovi (gha/leto),
i vrsta snovi (1),
j vrsta bioproizvodne površine (1),
h prevozno sredstvo,
u_i količina uvožene snovi i (t/leto),
e_i količina izvožene snovi i (t/leto),
p_i količina proizvedene snovi i (t/leto),
k_i spreminjevalni faktor za snov i (gha/t leto),
k_h spreminjevalni faktor za vrsto prevoza h (gha/kmt leto),
s prevožena razdalja snovi, ki jih uvozimo ali izvozimo, med mestom proizvodnje in mejo sistema (km).

Vrste živil in snovi, ki jih vključimo v obravnavo, izberemo tako, da zagotovimo mednarodno primerljivost raziskave [9].

where:
ES_s environmental footprints caused by material consumption (gha/year),
i type of material (1);
j type of bio-productive space (1);
h transport;
u_i amount of imported material i (t/year);
e_i amount of exported material i (t/year);
p_i amount of produced material i (t/year);
k_i conversion factor for material i (gha/t year);
k_h conversion factor for type of transport h (gha/kmt year);
s the distance covered between the production site and system's border with material being imported or exported (km).

The type of food and material taken into consideration must be selected in such a way that the research is comparable in international terms [9].

4 OKOLJSKE SLEDI PREBIVALCEV SLOVENIJE IN VPLIV OSKRBE Z ENERGIJO

Okoljske sledi prebivalcev Slovenije določimo po letni bilanci energijskih in snovnih tokov z enačbama (3) in (4). Posebno razlago

4 ENVIRONMENTAL FOOTPRINTS OF SLOVENIAN CITIZENS AND THE INFLUENCE OF ENERGY SUPPLY

The environmental footprints of Slovenian citizens are determined on the basis of the annual balance of energy and material flows with Equations (3) and (4).

Preglednica 2. *Okoljske sledi, ki so posledica oskrbe in rabe energije ter goriv (2002)*
Table 2. *Ecological footprints caused by energy and fuel supply and consumption (2002)*

	količina energije energy amount	**energijske površine energy space**	**kmetijske površine crop land**	**pašniki grazing land**	**gozdovi forests**	**vodne površine water space**	**pozidane površine built-up land**
	GWh/leto GWh/year	**(gha/prebivalca) (gha/capita)**					
zemeljski plin natural gas	10150	0,21					
UNP	1006	0,02					
motorni bencin[1] petrol[1]	9477	0,28					
dizelsko gorivo, EL kurilno olje[1] diesel fuel. EL fuel oil[1]	5925	0,26					
premog[2] coal[2]	2543	0,09					
lesna biomasa wood biomass	3060				0,02		
geotermalna energija geothermal energy	333						
sončna energija solar energy	28						
deponijski in bio plin depot and bio gas	52						
el. energija iz TE el. energy from thermal power plants	4815	0,39					
el. energija iz HE el. energy from hydroelectric power plants	3741						0,04
el. energija iz JE el. energy from nuclear power plants	5036	0,41					
uvoz el. energije import of el. energy	4232	0,34					
izvoz el. energije export of el. energy	5553	- 0,45					
vgrajena energija izvoženim izdelkom[3] embodied energy in exported products[3]		- 0,19					
skupaj total		**1,36**			**0,02**		**0,04**
	1,42						

Opomba: v preglednici prikazane vrednosti so zaokrožene na dve decimalni mesti
[1] vrednost je razlika med uvozom in izvozom energenta
[2] upoštevana le poraba za proizvodnjo toplote
[3] podatek, določen na podlagi količin prepeljanih snovi in povprečne razdalje 550 km [12]
Note: The values presented in the table are rounded up to two decimal points
[1] the value represents the difference between the import and export of energy product
[2] only the consumption for heat production is recognised
[3] datum determined on the basis of transported material over an average distance of 550 km [12]

izračuna okoljskih sledi zahteva primer ponovne uporabe snovi. Tako je na primer, glede na letno proizvodnjo, uvoz in izvoz izdelkov iz aluminija, komponenta energijskih površin okoljskih sledi izdelkov 297.889 gha (ali 0,15 gha/prebivalca). V viru [10] zasledimo, da v Sloveniji 16 % zavrženih

However, the presence of material re-use requires an additional explanation for the environmental-footprint calculation. For example, according to annual production, the import and export of aluminium products, the component of energy footprints for such products is equal to 297,889 gha (or 0.15 gha/capita). However,

Preglednica 3. *Okoljske sledi povprečnega prebivalca Slovenije v letu 2002*
Table 3. *Ecological footprints of an average Slovenian citizen in 2002*

ekološke sledi ecological footprints	**energijske površine (gha/preb) energy space (gha/capita)**	**kmetijske površine (gha/preb) crop land (gha/capita)**	**pašniki (gha/preb) grazing land (gha/capita)**	**gozdovi (gha/preb) forests (gha/capita)**	**vodne površine (gha/preb) water space (gha/capita)**	**grajeno okolje (gha/preb) built-up land (gha/capita)**	**skupaj (gha/preb) total (gha/capita)**
energije ES_E energy ES_E	1,36			0,02		0,04	**1,42**
hrane ES_H food ES_H	0,004 (0,15)[1]	0,88	0,38				**1,26**
snovi in odpadki ES_S material and waste ES_S	0,02 (0,95)[1]	0,04		0,83		0,19	**1,08**
grajenega okolja ES_G built-up land ES_G						0,08	**0,08**
skupaj total	1,38	0,92	0,38	0,85		0,31	**3,85**

[1]Opomba: Okoljske sledi zaradi rabe energije, ki pa so pri celostni metodi že upoštevane pri energijskih okoljskih sledeh.
[1]Note: Ecological footprints caused by energy consumption – with the integral method they are already recognised in the context of energy footprints

izdelkov iz aluminija recikliramo, pri tem se raba energije in tako tudi potrebne površine za asimilacijo toplogrednih plinov zmanjšajo za 95 % [11]. Zato se navidezno energijske površine pri oskrbi z izdelki iz aluminija zmanjšajo za 45.279 gha. To zmanjšanje okoljskih sledi pa upoštevamo zgolj pri komponentni metodi in ne tudi pri celostni, saj je raba energije že vključena v skupno energijsko bilanco. Preglednica 2 navaja energijske okoljske sledi prebivalcev Slovenije v letu 2002, skupne okoljske sledi pa navaja preglednica 3.

Iz preglednice 3 je razvidno, da raba energijske in energetske spremembe najpomembneje zmanjšujejo naravne neobnovljive vire in obremenujejo okolje, saj največ prispevajo k skupnim okoljskim sledem prebivalcev Slovenije. To potrjuje potrebo tako po zmanjšanju rabe energije kakor tudi nadomeščanju fosilnih goriv z obnovljivimi viri energije, katerih uporaba povzroča manjše okoljske pritiske. Predvsem zaradi velikega faktorja pridelka, ki je značilen za slovenske gozdove (2,42) predstavljajo ti pomemben ponor CO_2. Ob upoštevanju industrijske uporabe lesa pa znaša primanjkljaj ponora tega najpomembnejšega toplogrednega plina 0,21 gha na prebivalca. Dolgoročno bi utegnil biti za Slovenijo kritičen tudi primanjkljaj biološko proizvodnih površin za proizvodnjo hrane, ki znaša na prebivalca kar 0,43 gha. Izračun okoljskih sledi prebivalca Slovenije in primerjava z razpoložljivimi biološko proizvodnimi površinami pokaže, da je trenutno za Slovenijo značilen tako globalno (ΔED = - 1,95 gha/preb) kakor tudi lokalno (ΔED = - 1,3 gha/preb) neuravnotežen

within the references of this article [10], one can find that in Slovenia, 16% of thrown-away aluminium products are recycled; therefore, the energy consumption as well as the necessary areas for the assimilation of greenhouse gases decreases by 95% [11]. This results in an apparently decreased energy space, i.e., by 45,279gha, when aluminium products are used. Such a decrease in the environmental footprint is only recognised when using the component method, the integral method only accounts for the energy consumption in a total energy balance. Table 2 presents the energy footprints of Slovenian citizens in 2002, while Table 3 gives the total environmental footprints.

Table 3 clearly demonstrates that energy consumption as well as energy-conversion processes drastically reduce non-renewable natural resources and detrimentally affect the environment by contributing the most to the total environmental footprints of Slovenian citizens. This confirms the need to decrease energy consumption as well as to replace fossil fuels with renewable sources of energy, the usage of which would reduce the pressure on the environment. Slovenian forests are characterised by a high yield factor (2.42), which means they present a significant carbon-dioxide source/sink. However, when industrial wood consumption is taken into the account, the source/sink deficit of this most significant greenhouse gas amounts to 0.21gha per capita. In the long run, the deficit of bio-productive space intended for food production might be critical too, since it amounts to 0.43gha. A calculation of the environmental footprints of Slovenian citizens and a comparison with the available bio-productive space shows that, currently, Slovenia can be characterised by imbalanced development, both globally (ΔED = -1.95 gha/capita) and razvoj. Postavlja se vprašanje, ali lahko s smotrno rabo energije in večjim izkoriščanjem obnovljivih virov energije spremenimo trenutni primanjkljaj okoljskih sledi v presežek. Analizirali bomo obdobje do leta 2020, to je obdobje, ki ga vrednotijo najpomembnejši sprejeti razvojni dokumenti Republike Slovenije [18].

5 VPLIV OSKRBE IN RABE ENERGIJE NA OKOLJSKE SLEDI PREBIVALCEV SLOVENIJE V LETU 2020

5.1 Izbira vplivnih parametrov

Za napoved spreminjanja okoljskih sledi prebivalcev Slovenije je treba določiti vplivne parametre in napovedati njihove vrednosti ob koncu obdobja vrednotenja.

Spreminjanje števila prebivalcev v naslednjih dvajsetih letih ocenimo na podlagi populacijske napovedi. Ugotovimo, da se bo število prebivalcev Slovenije v opazovanem obdobju le malenkostno spremenilo - v letu 2020 naj bi v Sloveniji živelo 2,019.399 prebivalcev. Torej število prebivalcev Slovenije pri napovedi ne bo vplivni parameter.

Energijski in snovni tokovi v obdobju do leta 2020 ne bodo ostali nespremenjeni. Za napoved njihovega časovnega spreminjanja uporabimo oceno naraščanja industrijske rasti [18]. Posledično bo naraščanje industrijske proizvodnje in BDP povzročilo tudi povečevanje specifične površine stanovanj, kar bo vplivalo na rabo energije v splošnem sektorju. Pričakovane vrednosti navaja preglednica 4.

Napoved industrijske rasti bomo uporabili kot utežni faktor za napoved rabe energije in snovi, napoved naraščanja stanovanjskih površin pa za napoved rabe energije v stavbah. Pri tem bo šlo za linearno uteženje, na katerem bomo kasneje opazovali predlagane ukrepe energetske politike. Ekološke sledi, ki sledijo zgolj zaradi povečane rabe ob nespremenjenem ravnanju z energijo v letu 2020 navaja preglednica 5. To stanje vzamemo kot “ničelno stanje”.

locally (ΔED = -1.3 gha/capita). The question is whether rational energy consumption and a more extensive use of renewable energy sources can change the current environmental deficit into a surplus. Below is an analysis of the period up to 2020 – a period characterised by some of the most significant developmental documents adopted by the Republic of Slovenia [18].

5 THE INFLUENCE OF ENERGY SUPPLY AND CONSUMPTION ON THE ENVIRONMENTAL FOOTPRINTS OF SLOVENIAN CITIZENS IN 2020

5.1 Selection of the influential parameters

In order to forecast the changes in the environmental footprints of Slovenian citizens, one must define the influential parameters and forecast their values at the end of the evaluation period.

The change in the number of inhabitants in the next twenty years can be estimated on the basis of a population forecast. It is likely that the number of inhabitants of Slovenia will not change significantly during the observed period – in 2020, Slovenia should have about 2,019,399 inhabitants. In other words, the number of Slovenian citizens should not be an influential parameter in any environmental forecast.

Energy and material flows in the period up to 2020 will not remain unchanged. In order to forecast their change over time, an estimation of the increase in industrial growth needs to be employed [18]. An increase in industrial production and GDP will result in an increase in the specific housing space, which will further influence the energy consumption in the general sector. The expected values are presented in Table 4.

The forecast of industrial growth is also used as a weighting factor when forecasting energy and material consumption, while the forecasted increase in the housing space serves as a forecast for the energy consumption in buildings. Linear weighting will be employed, based on which the suggested measures of energy policy can be subsequently observed. The environmental footprints caused only by increased consumption, accompanied by unchanged energy handling in 2020, are presented in Table 5. This state will be referred to as the “zero state”.

Preglednica 4. *Napovedane stopnje industrijske rasti in specifične stanovanjske površine v Sloveniji za obdobje do 2020 [18]*
Table 4. *Forecasted levels of industrial growth and specific housing space in Slovenia during the period up to 2020 [18]*

	1997	2000	2005	2010	2015	2020
stopnja rasti fizičnega obsega proizvodnje level of growth in the physical volume of production	0,95	1	1,09	1,18	1,28	1,45
stanovanjska površina na prebivalca (m^2) housing space per capita (m^2)	24,7	25,5	26,5	27,1	27,5	29

Preglednica 5. *Pričakovane okoljske sledi kot posledica rabe energije ob nespremenjenem ravnanju*
Table 5. E*xpected environmental footprints as a result of energy consumption and unchanged handling*

	2000	2020
	gha/prebivalca / gha/capita	
fosilna goriva fossil fuels		
kapljevita fosilna goriva liquid fossil fuels	0,54	0,78
plinasta fosilna goriva gas fossil fuels	0,23	0,33
trdna fosilna goriva solid fossil fuels	0,09	0,13
od tega v stavbah in buildings	0,26	0,30
električna energija electric energy		
iz fosilnih goriv from fossil fuels	0,39	0,57
vodni potencial water potential	0,04	0,06
jedrska energija nuclear energy	0,41	0,59
od tega v stavbah in buildings	0,25	0,29
lesna biomasa wood biomass	0,02	0,03
uvoz električne energije import of electrical energy	0,34	0,49
izvoz električne energije export of electrical energy	-0,45	-0,65
vgrajena energija izvoženim izdelkom embodied energy in exported products	-0,19	-0,28
skupaj total	1,42	2,06

Preglednica 6. *Pričakovane okoljske sledi snovnih tokov in oskrbe s hrano prebivalcev Slovenije*
Table 6. *Expected environmental footprints in terms of material flow and the food supply of Slovenian inhabitants*

	2000	2020
	gha/prebivalca gha/capita	**gha/prebivalca gha/capita**
hrana food	1,26	1,34
snovi in odpadki materials and waste	1,08	1,57

Opomba: Vrednosti ne upoštevajo rabo energije, saj je že upoštevana v preglednici 5.
Note: Energy consumption is not included in these values, because it is already included in Table 5.

Za oceno snovnih tokov prav tako uporabimo napovedi industrijske rasti. Torej bo za ničelno stanje veljalo, da se bo tok surovin do leta 2020 povečal za 1,45-krat. Izjema je oskrba s hrano. Za razvite države, kamor prištevamo tudi Slovenijo, velja napoved, da se bo naraščanje potreb po hrani spreminjalo bistveno manj intenzivno kakor v nerazvitih [13]. Energijska vrednost zaužite hrane naj bi se v razvitih državah do leta 2020 povečala le za 6 %. Okoljske sledi prebivalcev Slovenije v letu 2020 kot posledico snovnih tokov in potreb po hrani navaja preglednica 6.

An industrial growth forecast is also used when estimating material flows. The zero state in this sense means that the flow of raw materials will increase by 1.45 times in the period up to 2020. An exception is food supply. The forecast for the group of developed countries, which includes Slovenia, suggests that food consumption will increase less significantly in the developed than in the undeveloped countries [13]. Up to 2020, the energy value of the consumed food should increase by only 6% in developed countries. The environmental footprints of Slovenian citizens in 2020 as a result of material flows and the need for food are presented in Table 6.

5.2 Napoved okoljskih sledi prebivalcev Slovenije do 2020

Glede na sprejete mednarodne obveznosti Slovenije in državne razvojne dokumente lahko oblikujemo različne scenarije, ki bodo v prihodnosti vplivali na zmanjšanje okoljskih sledi, ki so posledica rabe energije. Njihove cilje oblikujemo v tri scenarije: A, B in C. Ti vključujejo povečevanje učinkovitosti energijskih sprememb, zmanjšanje rabe energije in povečano izkoriščanje obnovljivih virov energije.

5.2 Forecast of the environmental footprints of Slovenian inhabitants up to 2020

Based on the adopted international obligations of Slovenia and the national developmental documents, various scenarios on a future decrease of environmental footprints caused by energy consumption can be shaped. Based on their goals, three scenarios can be envisaged, i.e., A, B and C, which include the increased efficiency of energy conversions, decreased energy consumption and the increased exploitation of renewable sources of energy.

Preglednica 7. *Napoved okoljskih sledi ob podvojitvi energije, pridobljene iz OVE [14]*
Table 7. *Forecast of the environmental footprints when doubling the energy from renewable sources [14]*

Vir energije **Energy source**	**dodatna pridobljena energija na leto (GWh/leto)** **additionally acquired energy per year (GWh/year)**	**okoljske sledi (gha/prebivalca)** **environmental footprints (gha/capita)**
podvojena uporaba trdne biomase double use of solid biomass		
proizvodnja toplote thermal production	3.060	0,02
proizvodnja električne energije production of electrical energy	306	$4,59*10^{-3}$
podvojena proizvodnja električne energije iz malih hidroelektrarn double production of electrical energy from small hydro-electric power plants	305	$2,75*10^{-3}$
uvajanje bioetanola kot dodatek neosvinčenemu bencinskemu gorivu; uporabili bi 18 % opuščenih kmetijskih površin v zadnjih letih introduction of bio-ethanol as an additive to unleaded petrol; 18% crop lands, not cultivated during past years, would be used .	556	$4,45*10^{-3}$
uvajanje biodizelskega goriva; uporabili bi 3% opuščenih kmetijskih površin v zadnjih letih introduction of bio-diesel fuel; 3% crop lands, not cultivated during past years, would be used	83	$0,66*10^{-3}$
proizvodnja bioplina, kar je okvirno 4% glede na ocenjen potencial živalske biomase biogas production – app. 4%, based on estimated potential of animal biomass	277	$2,8*10^{-3}$
izkoriščanje vetra; 12 vetrnic z imensko močjo 1,3 MW, v_{letno} =8m/s wind exploitation; 12 sails of windmill with maximum net power 1.3 MW, v_{yearly} = 8m/s	72	$0,14*10^{-3}$
potrojen delež izkoriščanja geotermalne energije triple share of geo-thermal energy exploitation		
električne energije iz geotermalnega vodonosnika Termal II electrical energy from "Termal II" geothermal aquifer	83	0
toplota geotermalnega vodonosnika Termal II heat from "Termal II" geothermal aquifer	83	0
sončna energija solar energy		
energija, ki predstavlja 100 % energije za pripravo tople sanitarne vode v vsako leto novo zgrajenih individualnih stavbah (5000 objektov na leto) energy representing 100% of the energy needed for heated sanitary water in new, individual buildings (5000 buildings per year)	139	$8,36*10^{-6}$
ogrevanje individualnih stavb in industrijskih objektov z nizko in srednjetemperaturnimi solarnimi sistemi heating of individual and industrial buildings with solar systems working with low and medium temperature	72	$4,32*10^{-6}$
skupaj / total	**5.175**	**0,04**

5.2.1 Scenarij A: Podvojitev energije, pridobljene iz obnovljivih virov energije (OVE)

Podvojitev energije, pridobljene iz obnovljivih virov, je strateški cilj EU, ki ga opredeljuje “Bela knjiga”. Za Slovenijo bi to pomenilo povečanje deleža primarne energije iz obnovljivih virov energije s 6% na 12 %. Možen scenarij [14] in nastale okoljske sledi navaja preglednica 7.

Z načrtovanim povečanjem izkoriščanja OVE bi bilo mogoče pridobiti letno 5.175 GWh energije. Okoljske sledi, ki jih povzročajo te tehnike, znašajo 0,04 gha/prebivalca, medtem ko so energijske okoljske sledi enake količine »fosilne« energije 0,21 gha/prebivalca. Pri tem smo upoštevali, da z OVE nadomestimo tisto energijo, pridobljeno iz fosilnih goriv, ki povzroča največje okoljske sledi. Celoten učinek scenarija A je torej zmanjšanje okoljskih sledi za 0,17 gha na prebivalca.

5.2.1 Scenario A: Doubling of the energy from renewable sources

Doubling of the energy from renewable source is a strategic goal of the EU, determined in the “White Book”. For Slovenia it means an increase in the share of primary energy from renewable sources from 6 to 12%. A possible scenario [14] and the resulting environmental footprints are presented in Table 7.

The planned increase in the exploitation of renewable sources of energy would bring 5,175GWh of energy each year. The environmental footprints resulting from such technologies amount to 0.04gha/capita, while the energy footprints resulting from the same amount of fossil-fuel energy amount to 0.21 gha/capita. Also, it was taken into account that fossil-fuel energy, which causes the largest environmental footprints, is replaced with a renewable source of energy. Based on the above, the outcome of scenario A is a decrease in the environmental footprints by 0.17 gha per capita.

Preglednica 8. *Raba energije in okoljske sledi po scenariju B ([15] do [17])*
Table 8. *Energy consumption and environmental footprints according to Scenario B ([15] to [17])*

Ukrep **Measure**	**GWh/leto** **GWh/year**	**okoljske sledi (gha/prebivalca)** **environmental footprints (gha/capita)**
Napotilo o energijski učinkovitosti stavb - Napotilo 2002/91/ES Evropskega parlamenta in sveta, 2000 [33] predvideva, da bo uvajanje presoje rabe energije v stavbah posredno pripomoglo k 20 % zmanjšani rabi energije v stavbah Directive on the energy performance of buildings – Directive 2002/91/EC of the European Parliament and of the Council, 2000 [33] anticipates that the introduction of judgement of energy use in buildings would indirectly contribute to decreased energy use in the buildings by 20%	4.444 (prihranjena energija) (saved energy)	- 0,13
Napotilo o proizvodnji električne energije iz OVE - Napotilo 2001/77/ES Evropskega parlamenta in sveta, 2001, [32] sprejeta obveza Slovenije je povečanje sedanjega deleža proizvedene električne energije iz 33% na 36% Directive on electricity production from renewable energy sources – Directive 2001/77/EC of the European Parliament and of the Council, 2000 [32]; Slovenia adopted an obligation to increase the current share of electricity produced from 33% to 36%	1.480 (zamenjava fosilnih goriv) (replacing fossil fuels)	0,01
Napotilo o biogorivih - Napotilo 2003/30/ES Evropskega parlamenta in sveta, 2000, [34] predvideva do leta 2020 20% zamenjavo fosilnih tekočih goriv z gorivi proizvedenimi iz biomase ali vodika, ki bi bil proizveden z uporabo OVE Directive on bio-fuels – Directive 2003/30/EC of the European Parliament and of the Council, 2000 [34] anticipates that by 2020, 20% of liquid fossil fuels should be replaced with fuels produced from biomass or hydrogen produced by using renewable sources of energy	3.634 (zamenjava fosilnih goriv) (replacing fossil fuels)	0,03
skupaj **total**	**4.444 prihranjeno/saved** **5.114 pridobljeno/acquired**	**- 0,13** **- 0,19**

5.2.2 Scenarij B: Uveljavitev navodil EU s področja varčne rabe energije in izkoriščanja OVE

V zadnjih letih je EU sprejela vrsto navodil, katerih cilj je zmanjšanje rabe energije in s tem tudi odvisnosti od zunanjih energetskih virov. Dosledna uveljavitev sprejetih napotil EU s področja varčne rabe energije in izkoriščanja OVE ([15] do [17]) v Sloveniji drugi scenarij (B), ki ga ocenjujemo. V preglednici 8 so predstavljeni pričakovani učinki sprejetih in uveljavljenih navodil.

Glede na scenarij B bi lahko v stavbah prihranili letno 4444 GWh energije ob hkratnem zmanjšanju okoljskih sledi za 0,13 gha/prebivalca. Energija, pridobljena iz obnovljivih virov, (0,04 gha/prebivalca) pa pomeni zamenjavo »fosilne« energije (0,23 gha/prebivalca). Celoten učinek scenarija B je zmanjšanje okoljskih sledi za 0,32 gha/prebivalca, glede na napovedano ničelno stanje.

5.2.3 Scenarij C: Resolucija o državnem energetskem programu

Tretji scenarij povzamemo po dokumentu Predlog Resolucije o državnem energetskem

5.2.2 Scenario B: Implementation of EU directives in the area of the economical use of energy and the exploitation of renewable sources of energy

In recent years the EU has adopted a variety of directives with the aim of decreasing energy consumption and the dependency on external sources of energy. A consistent implementation of adopted EU directives in the area of the economical use of energy and the exploitation of renewable sources of energy ([15] to [17]) in Slovenia represents the second scenario, B, which is evaluated below. Table 8 presents the expected outcomes resulting from adopted and implemented directives.

According to scenario B we might save 4,444 GWh of energy per year; at the same time, the environmental footprints would decrease by 0.13 gha/capita. The energy produced from renewable sources (0.04 gha/capita) represents the replacement of fossil-fuel energy (0.23gha/capita). Based on the above, the overall outcome of scenario B is a decrease in the environmental footprints by 0.32 gha per capita, based on the proposed zero state.

5.2.3 Scenario C: The national energy programme resolution

The third scenario is based on the document entitled National Energy Programme Resolution Proposal,

Preglednica 9. *Okoljske sledi ob upoštevanju scenarija C [18]*
Table 9. *Environmental footprints based on scenario C [18]*

	2000	**2020**
	gha/prebivalca / gha/capita	
fosilna goriva **fossil fuels**		
kapljevita fosilna goriva liquid fossil fuels	0,54	0,59
plinasta fosilna goriva gas fossil fuels	0,23	0,31
trdna fosilna goriva solid fossil fuels	0,09	0,04
električna energija **electrical energy**		
termoelektrarne thermal power plants	0,39	0,50
hidroelektrarne hydroelectric power plants	0,04	0,05
jedrska elektrarna nuclear power plant	0,41	0,46
elektrarne na biomaso biomass power plants		0,01
lesna biomasa - toplota **wood biomass heat**	0,02	0,03
uvoz električne energije import of electrical energy	0,34	0
neto izvoz električne energije net export of electrical energy	- 0,45	- 0,22
vgrajena energija izvoženim izdelkom embodied energy in exported products	- 0,19	- 0,28
skupaj / total	**1,42**	**1,49**

programu [18], ki ga predlaga MOPE. Za izračun okoljskih sledi bomo povzeli podatke o energetskih bilancah, ki so objavljene v tem dokumentu in so prikazane v preglednici 9. Glede na scenarij C se bodo okoljske sledi zaradi rabe energije, glede na ničelno stanje, zmanjšale za 0,36 gha/prebivalca.

Velik delež energijskih površin pri oskrbi s snovmi in hrano, ki je prikazan v preglednici 2 poudarja pomen smotrne rabe snovi tudi v smislu oskrbe z energijo. Če bi v Sloveniji uspešno uvedli strategijo "brez odpadkov" ravnanja z naravnimi snovmi, ki jo uspešno uveljavljajo na primer v Canberri in Seattlu, bi občutno zmanjšali tudi energijske okoljske sledi. Pri analizi upoštevamo, da je možnost ponovne uporabe snovi količinsko omejena zaradi izgub pri predelavi in neustaljenih postopkov (kopičenja snovi), tako da lahko ponovno uporabimo 50 % zavrženih snovi. Učinek takega ravnanja navaja preglednica 10.

which was proposed by the Ministry of the Environment, Spatial Planning and Energy. In order to calculate the environmental footprints, the data on energy balances contained in this document will be summarized. The data are presented in Table 9. According to Scenario C, the environmental footprints caused by energy consumption would decrease by 0.36 gha/capita, based on the proposed zero state.

The large share of energy space for material and food supply, shown in Table 2, emphasises the importance of rational material use in the context of energy supply. If Slovenia managed to successfully implement the so-called "no waste" strategy in terms of handling natural materials, like, for example, Canberra or Seattle, our environmental footprints would significantly decrease. This analysis recognises the fact that material reuse is limited in terms of quantity due to the loss resulting from recovery and non-stationary processes (matter accumulation), which means that only 50% of thrown-away materials can be reused. The outcome of such handling is presented in Table 10.

Preglednica 10. *Zmanjšanje okoljskih sledi pri uvedbi strategije "brez odpadkov"*
Table 10. *The decrease of environmental footprints as a result of the implemented "no waste" strategy*

	energijske površine energy space	**kmetijske površine** crop land	**pašniki** grazing land	**gozdovi** forests	**pozidane površine** built-up land	**vodne površine** water space
	okoljske sledi (gha) / environmental footprints (gha)					
	- 0,52	- 0,009		- 0,60	- 0,13	
skupaj total	**- 1,26 gha/prebivalca gha/capita**					

Preglednica 11. *Predvidene okoljske sledi prebivalcev Slovenije v 2020 ob upoštevanju navedenih scenarijev in strategij*
Table 11. *Forecasted environmental footprints of Slovenian citizens in 2020 based on scenarios A, B and C.*

	Okoljske sledi (gha/prebivalca) / Environmental footprints (gha/capita)				
	stanje state in	**ničelno stanje zero state**	**scenariji smotrne rabe energije in snovi scenarios of rational energy and material consumption**		
	2002	**2020**	**2020**		
			A	**B**	**C**
energija energy	1,42	2,10	1,28	1,26	1,53
neposredna raba energije direct use of energy	1,39	2,06	2,06 + 0,04 – 0,21 – 0,13- 0,52	2,06 – 0,32 -0,52	1,49 – 0,52
energija, potrebna za oskrbo s snovmi, ki jih uvozimo energy necessary for supply from imported materials	0,03	0,04	0,04	0,04	0,04
hrana food	1,26	1,34	1,34	1,34	1,34
surovine in odpadki raw materials and waste	1,08	1,57	0,47	0,47	0,47
odstranjevanje odpadkov waste disposal	0,14	0,27	0,00	0,00	0,00
raba surovin use of raw material	0,94	1,34	0,47	0,47	0,47
grajeno okolje built-up land	0,08	0,09	0,09	0,09	0,09
skupaj / total	**3,85**	**5,10**	**3,28**	**3,26**	**3,01**

Napoved okoljskih sledi prebivalcev Slovenije v 2020 ob upoštevanju scenarijev A, B in C pri oskrbi z energijo ter predlaganega smotrnega ravnanja s snovmi navaja preglednica 11.

6 SKLEP

Namen dela je bil večplasten. Na teoretični ravni smo želeli ugotoviti omejitve in izbrati najprimernejšo metodo določitve okoljskih sledi kot metodo merjenja uravnoteženega razvoja nekega sistema. Glede na opravljeno raziskavo lahko povzamemo:

– Metodo okoljskih sledi odlikujejo številne lastnosti, ki jih morajo izpolnjevati celoviti kazalniki; gre za enopomensko vrednost, ki je predstavljiva; prva odločitev, ki jo moramo sprejeti pri uporabi te metode, pa je povezana z celostnim in komponentnim načelom; celostno načelo, ki smo ga uporabili za Slovenijo, je v osnovi laže uporabiti na statistično dobro obdelanih sistemih; pri delu pa smo ugotovili, da so energijski tokovi lahko merljivi, mnogo teže je slediti snovnim.
– Največjo težavo pri celostni metodi pomeni problem dvojnega štetja, še posebej pri analizi energijskih tokov.
– Naša ugotovitev je tudi, da z razpoložljivimi statističnimi podatki ni mogoče križno ugotavljanje (preverjanje) tokov snovi in odpadkov, kar bi izboljšalo natančnost metode.
– Ne glede na dejstvo, da osnovno pravilo metode upošteva največje znane vplive na okolje (za primer je izračun okoljskih sledi grajenega okolja, kjer predpostavimo, da to zaseda najkakovostnejše kmetijske površine) in dejstva, da so upoštevane vse pomembne snovi, so okoljske sledi praviloma podcenjene.

Na uporabni ravni pa smo želeli ovrednotiti okoljske sledi prebivalcev Slovenije v sedanjem trenutku in leta 2020 ob upoštevanju različnih scenarijev smotrne rabe energije, zamenjave fosilnih goriv in izkoriščanja obnovljivih virov energije. Gre za obdobje, ki ga obravnava večina razvojnih dokumentov. Naše ugotovitve lahko strnemo v naslednje:

– Trenutne okoljske sledi prebivalcev Slovenije (3,85 gha/preb) presegajo razpoložljivo biološko proizvodno površino (2,55 gha/preb) in bistveno presegajo planetarno razpoložljivo bioproizvodno površino (1,9 gha/preb), torej je za Slovenijo značilno tako lokalno kakor tudi globalno neuravnotežen razvoj.
– Primerjava z državami EU (sl. 4) pokaže, da so okoljske sledi prebivalcev Slovenije med najnižjimi; ob primerjavi okoljskih sledi držav Evropske zveze ugotovimo, da imajo samo Finska, Irska, Latvija in Švedska manjše okoljske sledi od njihove biološke

The forecast of environmental footprints for Slovenian citizens in 2020 based on scenarios A, B and C in terms of energy supply as well as the suggested rational material handling is presented in Table 11.

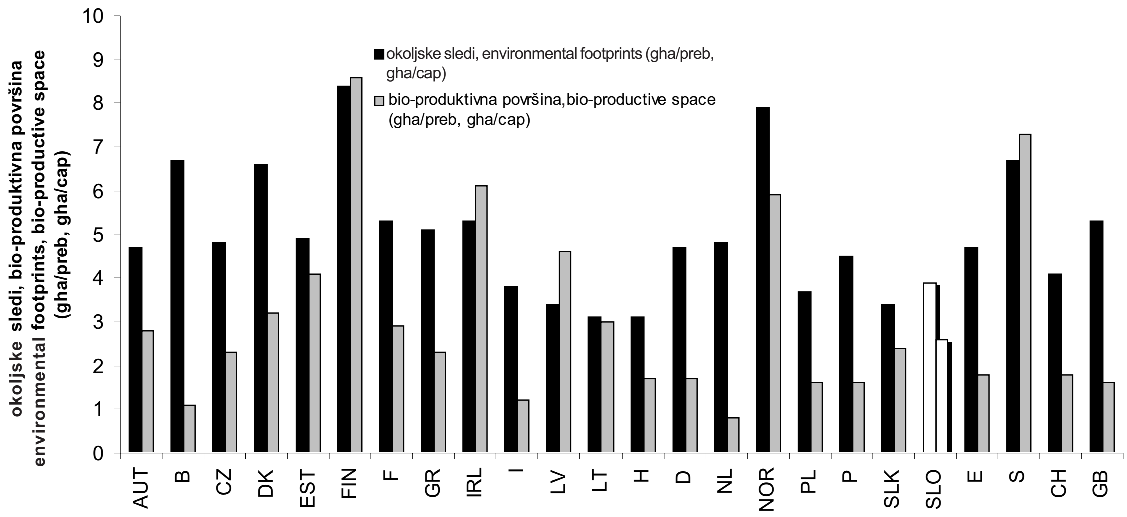
6 CONCLUSION

The purposes of this article are many fold. At the theoretical level, we wanted to find limits and choose the most appropriate method for determining environmental footprints – a method for measuring the sustainable development of a given system. Based on the performed research, the following can be concluded:

– the environmental footprints' method excels in many features that are mandatory for integral indicators; it presents a meaningful value that can be easily imagined; the first decision that has to be reached when using this approach involves a choice between the integral and component methods; the integral method that was used in the case of Slovenia is basically more applicable in systems that are statistically well analysed; our research found that energy flows are much easier to measure than material flows, which are more problematic in terms of tracking.
– the biggest problem when applying the integral method is double accounting, especially at the point where the energy flows are analysed;
– another finding is that the available statistical data do not allow the cross-sectional findings of material and waste flows, which would make the method more accurate.
– despite the fact that the basic rule of this method recognises the highest values in terms of influencing the environment (an example is the calculation of the environmental footprints of built-up land, where the assumption is that it occupies the most qualitative crop land) and the fact that all the significant materials are recognised, the environmental footprints are, as a rule, still underestimated.

At the applicable level we wanted to evaluate the current environmental footprints of Slovenian citizens as well as to forecast the environmental footprints in 2020 by considering various scenarios of the rational use of energy, the replacement of fossil fuels and the exploitation of renewable sources of energy. The period analysed is equal to a period mentioned in most developmental documents. Our findings may be summarized as follows:

– the current environmental footprints of Slovenian citizens (3.85 gha/capita) exceed the available bio-productive space (2.55 gha/capita) and significantly exceed the planetary bio-productive space (1.9gha/capita); therefore, Slovenia is characterised as a country with an imbalanced development, both locally and globally;
– a comparison with EU states (Figure 4) shows that the environmental footprints of Slovenian citizens are among the lowest; furthermore, the comparison of the environmental footprints of the EU states reveals that only Finland, Ireland, Latvia and Swe-



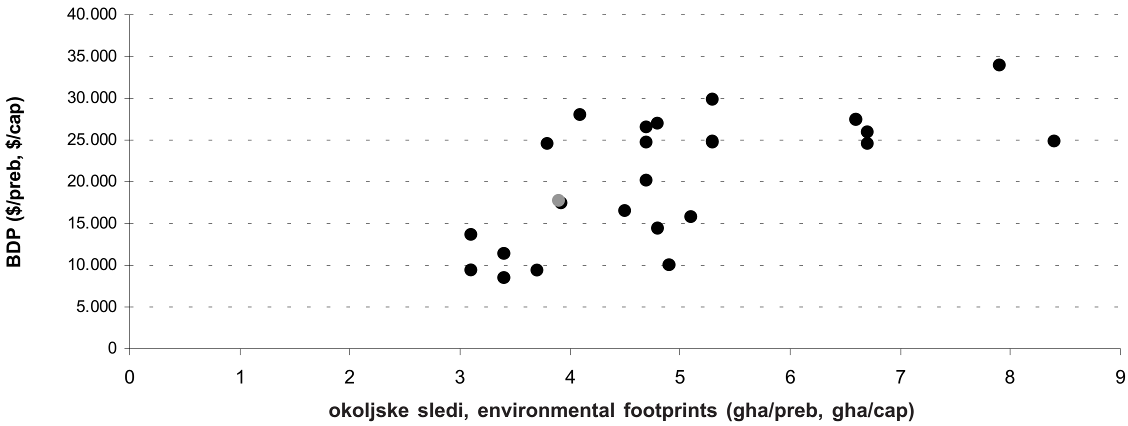
Sl. 4. *Ekološke sledi prebivalcev držav EU in velikost biološko-proizvodnih površin v teh državah ([3], [4] in [9])*
Fig. 4. *Environmental footprints of EU states and the amount of bio-productive space in these countries ([3], [4] and [9])*

proizvodnosti, torej presežek okoljskih sledi – v primeru Finske in Švedske je razlog v veliki površini gozda (7 oz. 5,4 gha/prebivalca), za Irsko so značilne velike vodne biološko proizvodne površine (1,66 gha/prebivalca), le za Latvijo velja, da ima razmeroma majhne okoljske sledi (3,1 gha/prebivalca) ob veliki površini za absorpcijo toplogrednih plinov (2,8 gha/prebivalca).

– Primerjava okoljskih sledi in najbolj značilnega ekonomskega kazalnika bruto domačega proizvoda (BDP) za države Evropske zveze pokaže opazno povezanost med naraščanjem okoljskih sledi in naraščanjem BDP (sl. 5); v območju okoljskih sledi med 3,5 in 5 gha na prebivalca pa opazimo velika odstopanja v BDP analiziranih držav (med 10.000 in 30.000 $). Torej je v tem področju, ki je tudi najbolj značilno, mogoče močno povečati BDP ob nespremenjenih okoljskih sledeh!

den have lower environmental footprints in comparison with their bio-productivity; however, the environmental surplus in the case of Finland and Sweden results from the extensive forests (7 and 5.4 gha/capita), while a huge water bio-productive space is characteristic for Ireland (1.66 gha/capita); only Latvia has a relatively low environmental footprint (3.1 gha/capita) and a large space for the absorption of greenhouse gases (2.8 gha/capita).

– the comparison between the environmental footprints and the GDP (the most significant economic indicator) of the EU countries reveals a significant, positive correlation (Figure 5); furthermore, one can see that for environmental footprints between 3.5 and 5 gha the per-capita GDP ranges between $10,000 and $30,000, which means that there is a possibility to increase GDP and still leave the environmental footprints unchanged.



Sl. 5. *Povezanost med BDP in okoljskimi sledmi držav Evropske zveze; poudarjena točka pomeni Slovenijo [9]*
Fig. 5. *Correlation between the GDP and the environmental footprints of EU countries; the highlighted point represents Slovenia [9]*

- Prizadevanja k smotrni rabi energije sicer vodijo k izpolnjevanju mednarodnih obvez Slovenije glede na zmanjšanje emisij toplogrednih plinov, vendar ne zadoščajo za zagotavljanje lokalno sonaravno uravnoteženega razvoja.
- Lokalno sonaravno uravnotežen razvoj Slovenije bo v naslednjih desetletjih mogoče doseči zgolj:
  - z doslednim upoštevanjem scenarijev o oskrbi z energijo, ki izhajajo iz sprejetih Napotil EU in opredelitev v državnih razvojnih dokumentih;
  - s smotrno rabo snovi in popolnoma spremenjenim upravljanjem z odpadki, pri čemer prevladuje zmanjšanje črpanja neobnovljivih virov in ne njihovo energijsko izkoriščanje;
  - s povečanjem faktorja pridelka hrane na raven, ki ga že dosegajo nekatere druge evropske države – na primer Irska in Belgija.

- Efforts directed towards the rational use of energy will lead to the fulfilment of the international obligations of Slovenia with regard to reducing the emission of greenhouse gases; however, they are not sufficient for sustainable development at the local level.
- the sustainable development of Slovenia at the local level will be possible, based on the following:
  - a consistent compliance with energy-supply scenarios, which originate in adopted EU directives, and definitions from national developmental documents;
  - a rational consumption of materials and a completely changed waste-handling process, where a policy of a reduced extraction of non-renewable sources should prevail over their exploitation for energy.
  - an increased level of food production, which should reach that of some European countries, e.g., Ireland and Belgium.

7 LITERATURA
7 REFERENCES

[1] Wackernagel, M., W.E. Rees: Our ecological footprint, Reducing Human Impact on the Earth

[2] Lavrence, Onisto, Krause, Wackernagel (1998) How big is Torontos ecological footprint? *Murphy*

[3] Living Planet Report 2002, Redefining Progres 2003, *WWF*

[4] http://www.redefiningprogress.org, (26.9.2003)

[5] http://www.panda.org, (5.1.2003)

[6] Chambers, N., C. Simons, M. Wackernagel: Sharing natures interest, Ecological footprints as an indicator of sustainbility

[7] Statistični letopis Republike Slovenije 2002, *SURS*

[8] Matijašić (2003) Oddelek za gozdnogospodarsko načrtovanje, *Zavod za gozdove Slovenije*, Ljubljana

[9] Žun, Š. (2004) Ekološko sledenje razvoja lokalnih skupnosti, Magistrsko delo, *Fakulteta za strojništvo*, Ljubljana

[10] Strokovni posvet za sodobno gospodarjenje z odpadki: Skupaj za okolju prijazno prihodnost, Dunaj - Ljubljana 2003

[11] To good to throw away (2002) *NRDC*

[12] Prvo državno poročilo Konferenci pogodbenic Okvirne konvencije ZN o spremembi podnebja (2002) *Republika Slovenija, MOPE*, Ljubljana

[13] Lomborg (2001) The skeptical environmentalist, Cambridge

[14] Medved s sodelavci (2002) Program izrabe OVE, *Fakulteta za strojništvo*, Ljubljana

[15] Napotilo 2001/77/ES Evropskega parlamenta in sveta, 2001

[16] Napotilo 2002/91/ES Evropskega parlamenta in sveta, 2000

[17] Napotilo 2003/30/ES Evropskega parlamenta in sveta, 2000

[18] Predlog Resolucije o nacionalnem energetskem programu (2003) *Republika Slovenija, MOPE*, Ljubljana

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