Optimisation modelling for the design of sustainable diets

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Twitter: @DuurzaamEten

SYMPOSIUM

CLIMATE CHANGE, NUTRITION AND HEALTH:

GLOBAL CHALLENGES AND POTENTIAL SOLUTIONS

HEIDELBERG, MAY 5-7, 2021

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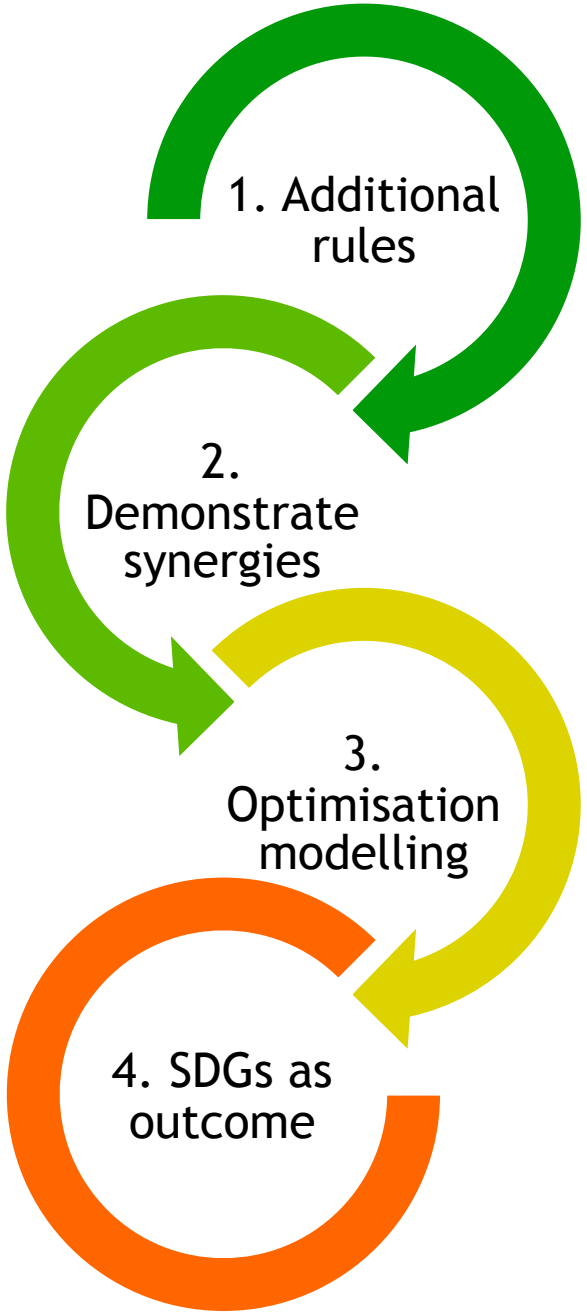
Voedingscentrum

Affiliation

- Netherlands Nutrition Centre (Voedingscentrum) 2007-2021
- May 1st 2021: Senior Advisor Sustainable Diets, World Wildlife Fund – NL

Sustainable Healthy Diets:
new definition WHO/FAO (2019)

- "Sustainable Healthy Diets are dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable.
- …. And support the preservation of biodiversity and planetary health."



How to incorporate sustainability into dietary guidelines?

4 approaches

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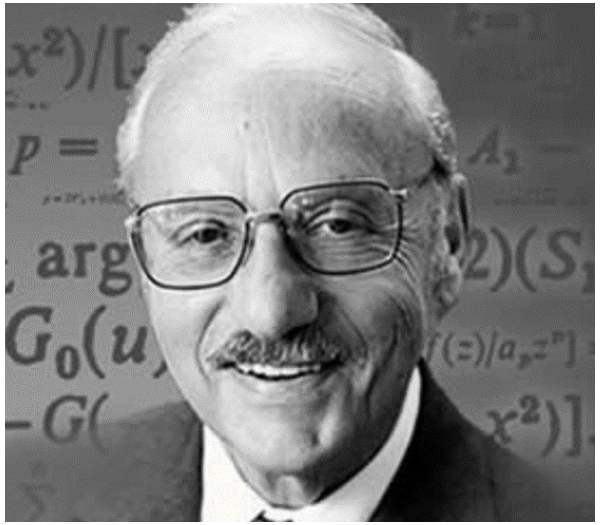
‘The Diet Problem’

For a moderately active man weighing 154 pounds, how much of each of 77 foods should be eaten on a daily basis so that the man’s intake of nine nutrients will be at least equal to the recommended dietary allowances (RDAs) suggested by the National Research Council in 1943, with the cost of the diet being minimal?

1943, George Stigler

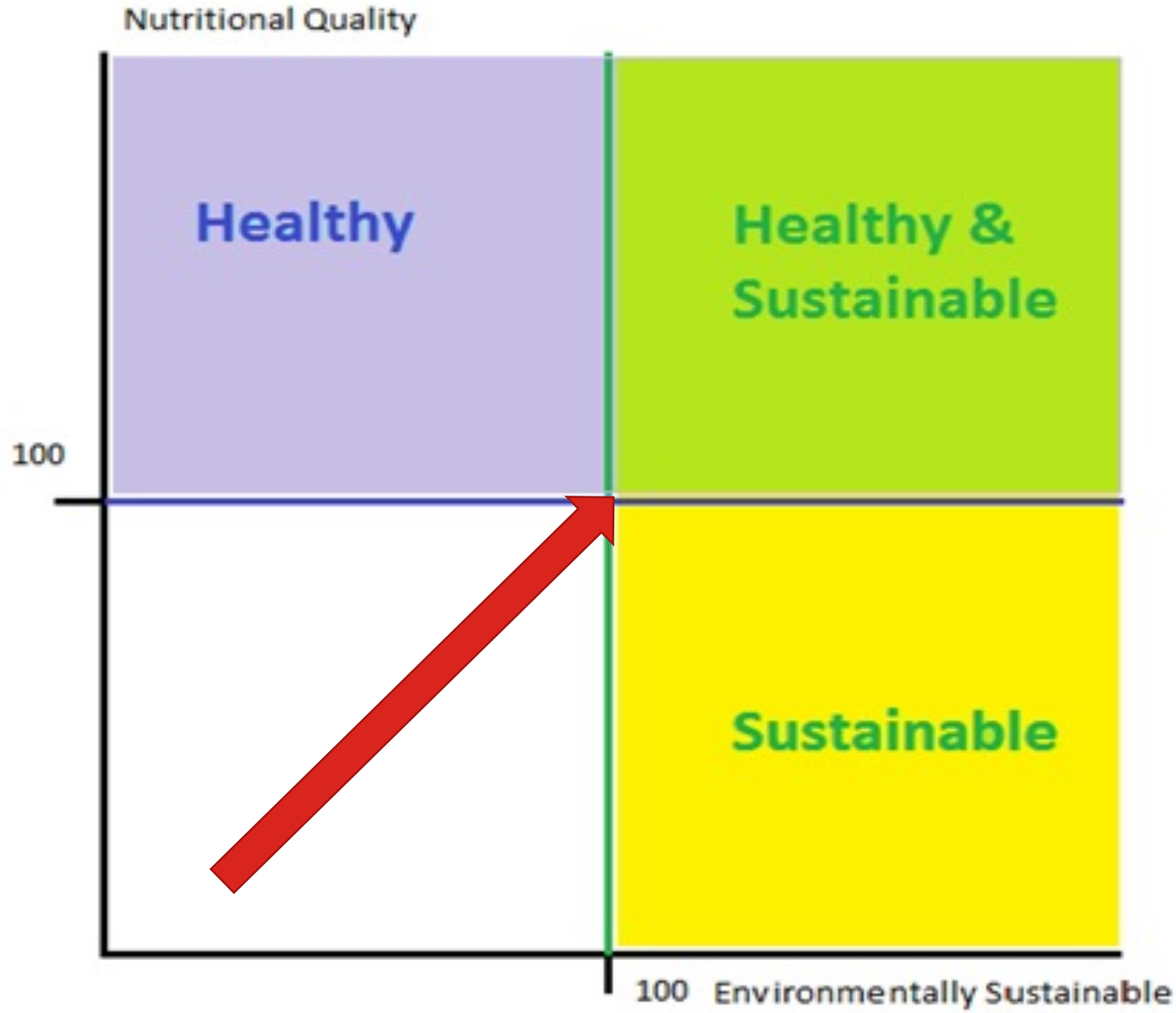


1947, George Dantzig

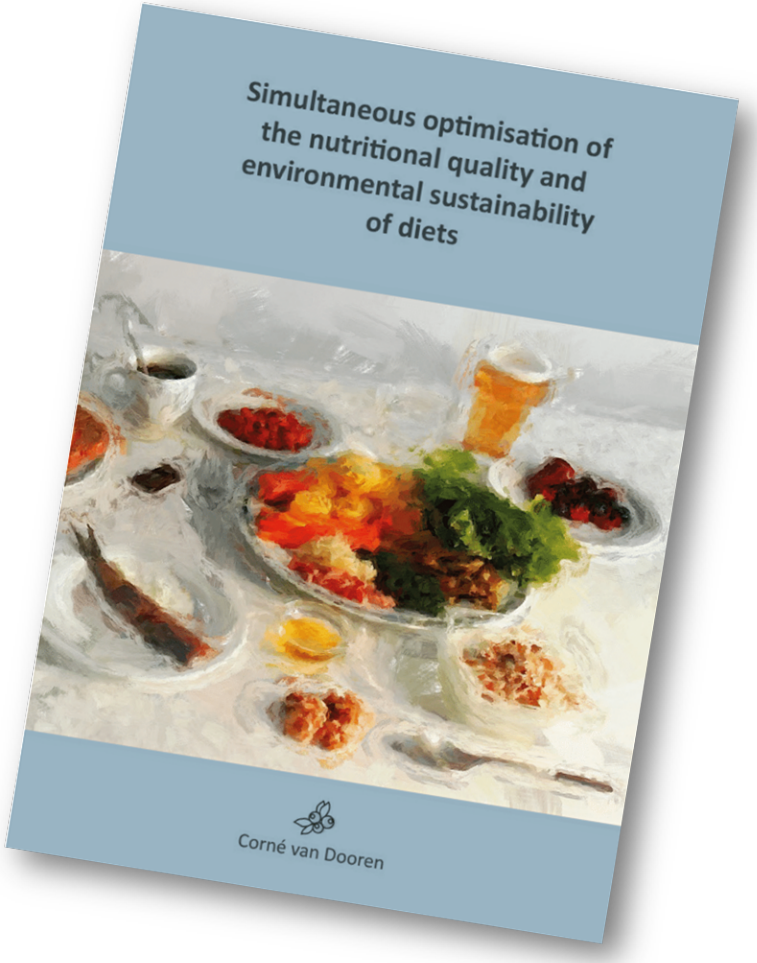
Linear programming: Simplex method

Looking for the optimal ‘green’ solutions

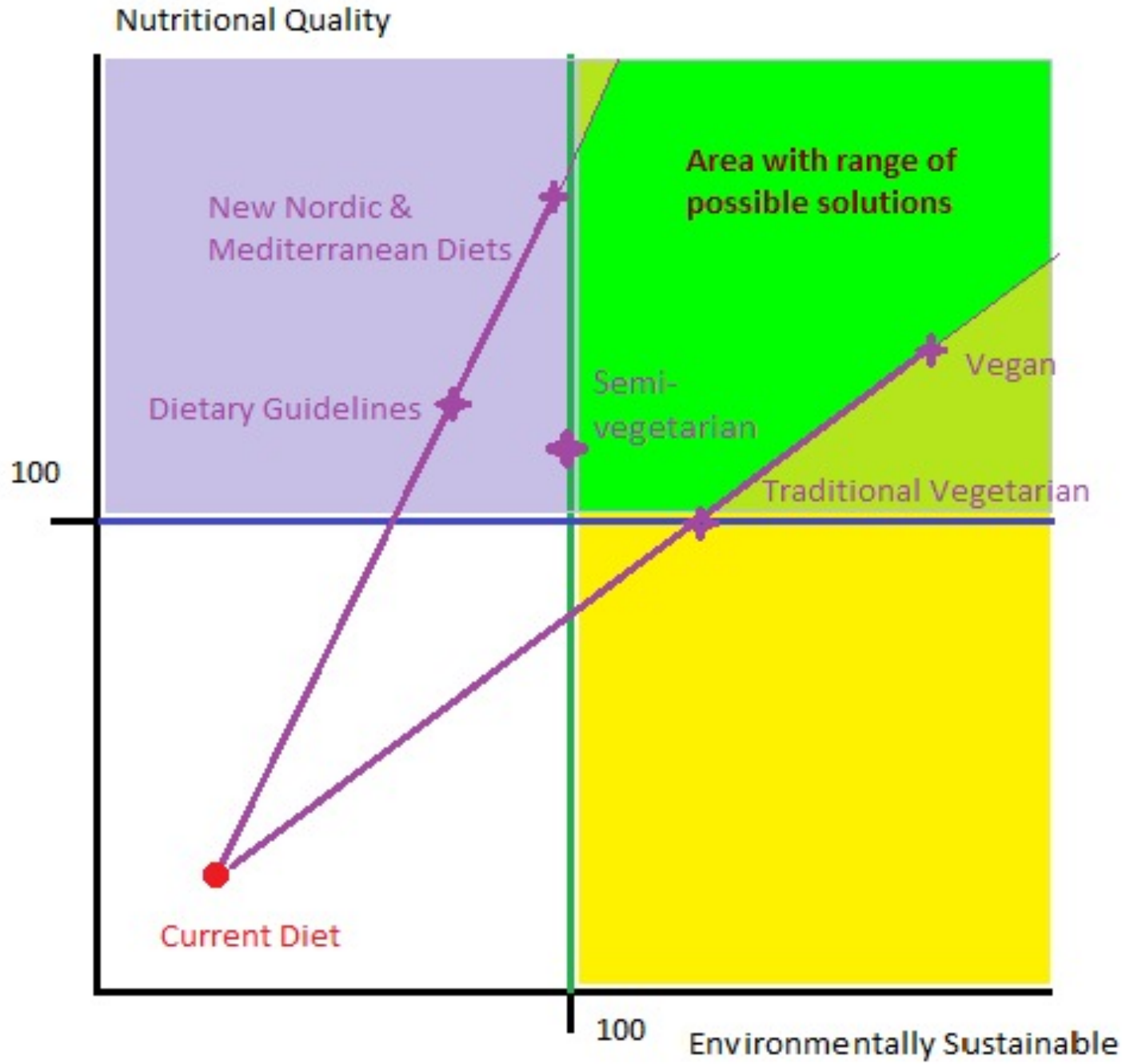
- Constraints on nutrients (healthy)
- Constraints on environmental impact (sustainable)
- As close as possible to the current diet



Range of diets



(van Dooren, 2018)



Acceptability constraints versus reduction goal ‘As close as possible to current diet’

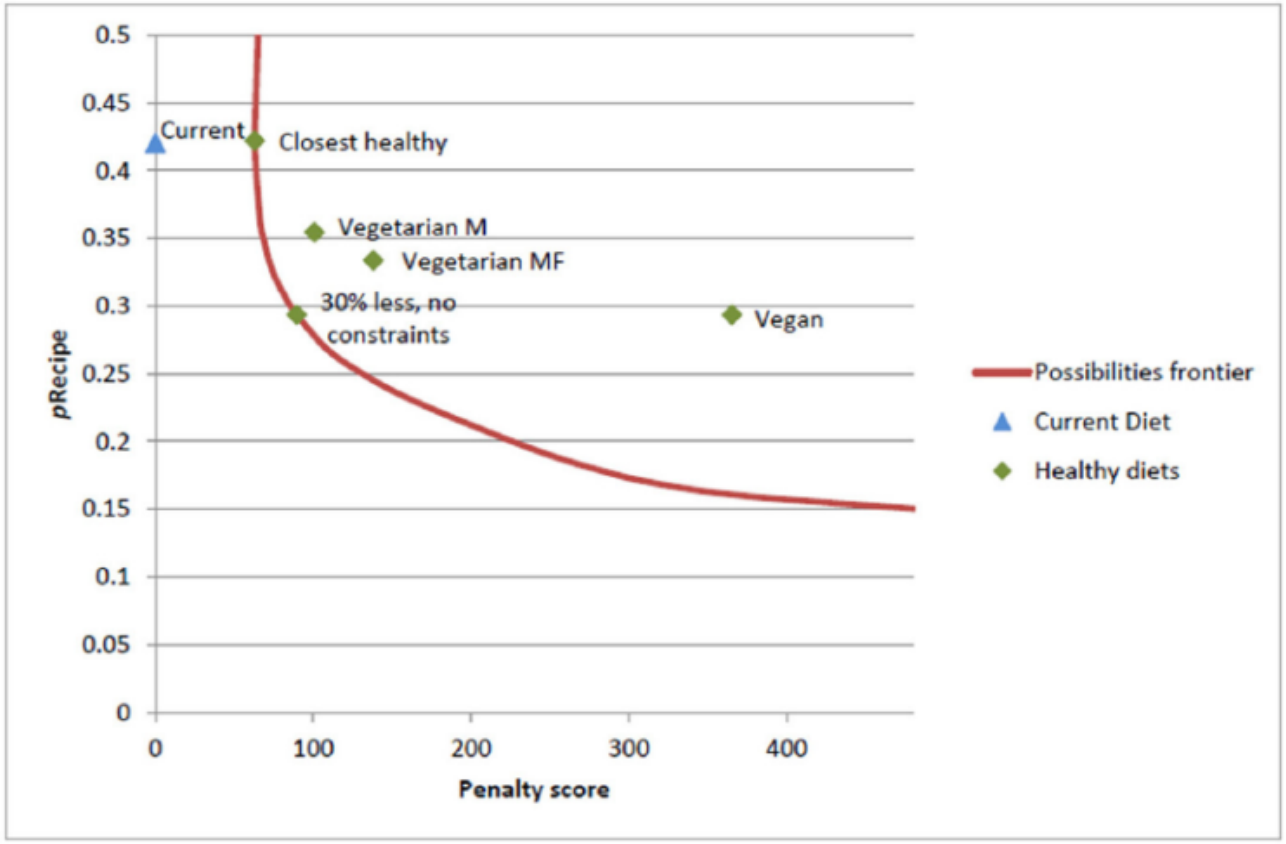


FIGURE 3 | Example of the application of acceptability constraints and the effects on the environmental impact of different diet scenarios (M, males; F, females). The lower the penalty score is, the closer the diet is to the current diet and the more acceptable (21). The red line is called the “possibilities frontier.” It indicates the possibilities with the lowest penalty score for a certain environmental constraint (21).

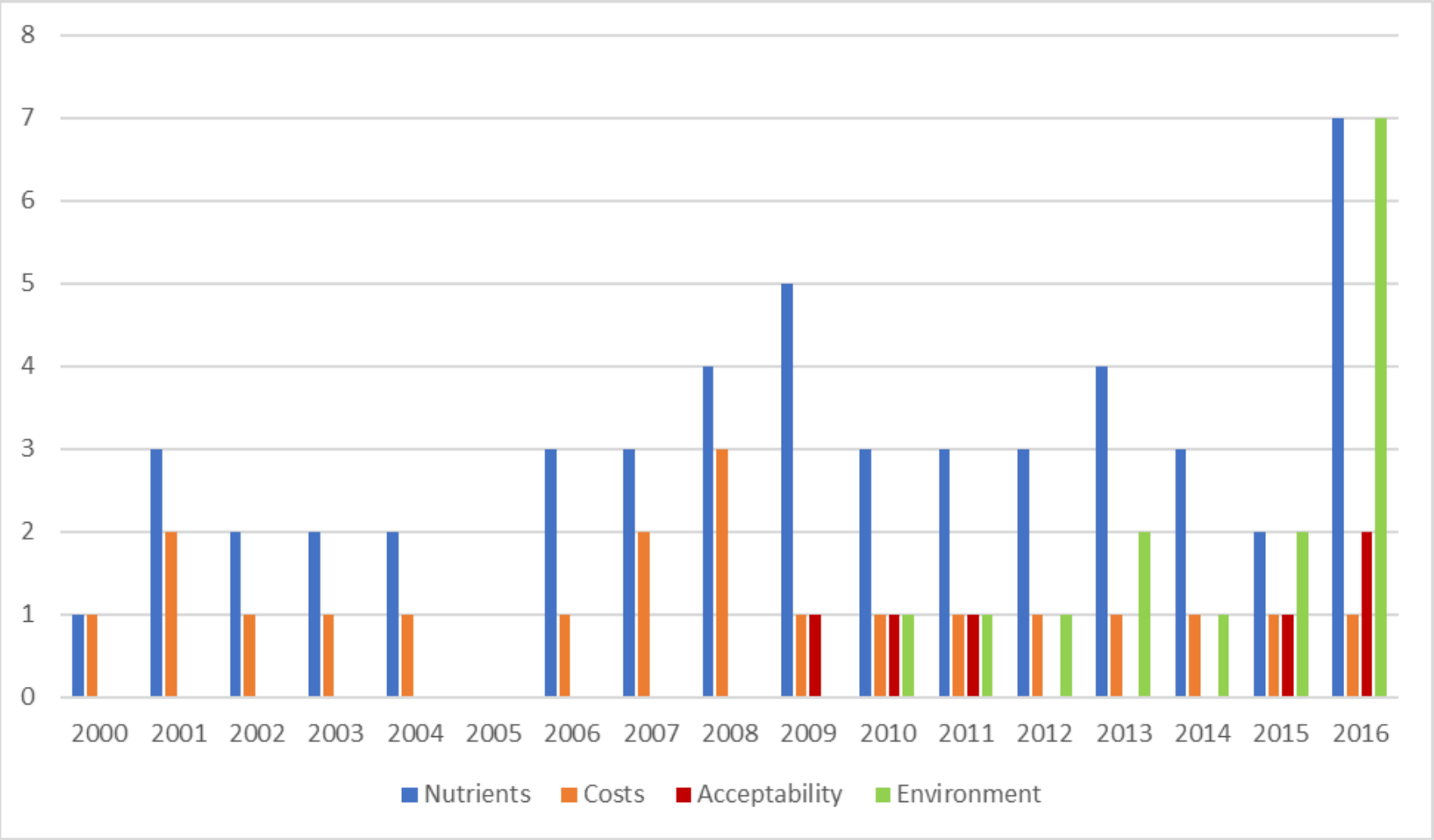
(Tyszler et al, 2015)

A Review of the Use of Linear Programming to Optimize Diets, Nutritiously, Economically and Environmentally

(Frontiers in Nutrition, van Dooren, 2018)

- 52 studies (2000-2016).
- 12 studies that applied ecological constraints (3 with Optimeal).
- Weaknesses: a small number of food items and/or nutritional constraints.
- Introducing acceptability constraints is recommended (but no study has provided the ultimate solution to calculating acceptability).

Increase in diet studies looking at environmental and acceptability constraints



(van Dooren, 2018)

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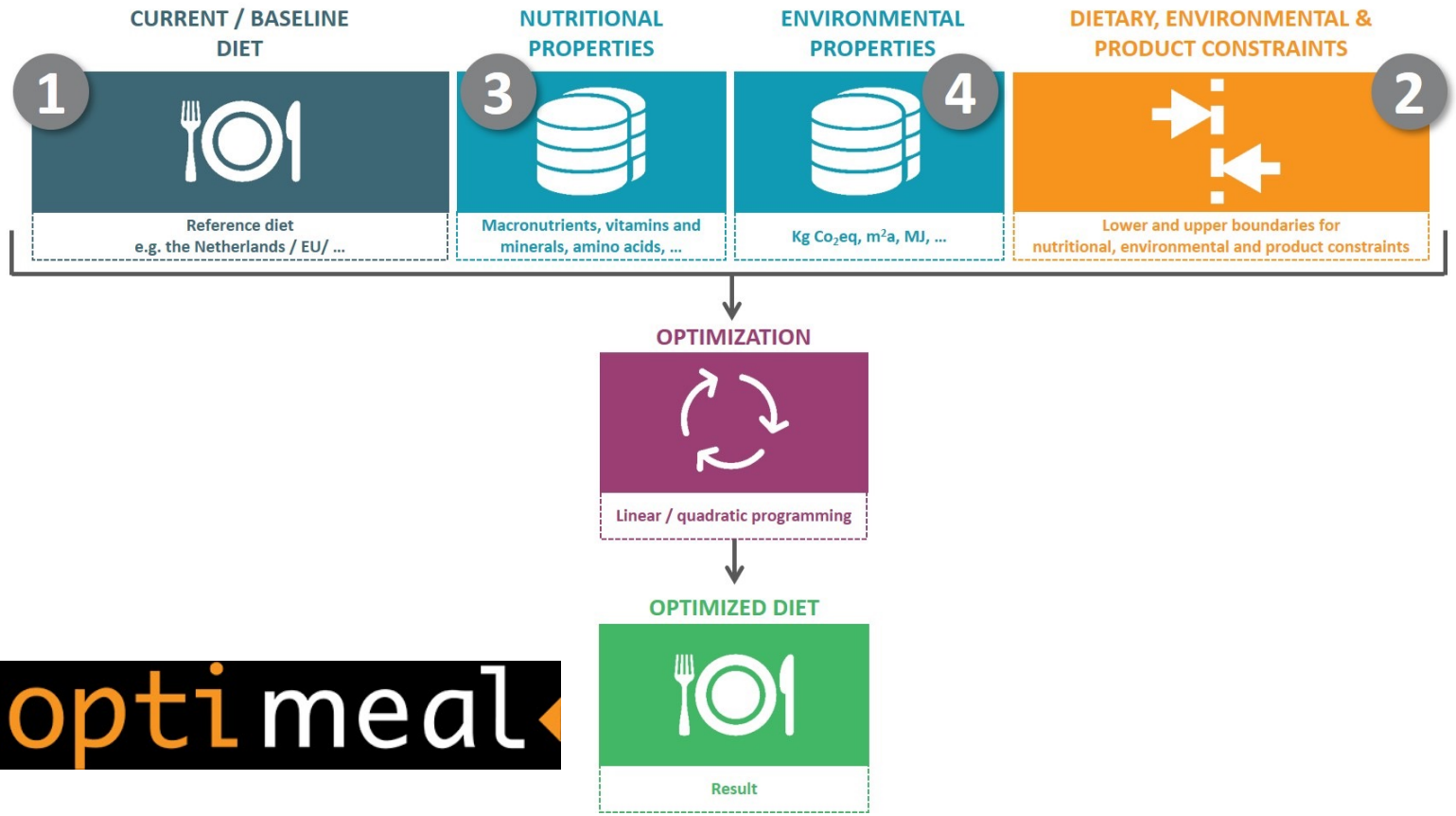
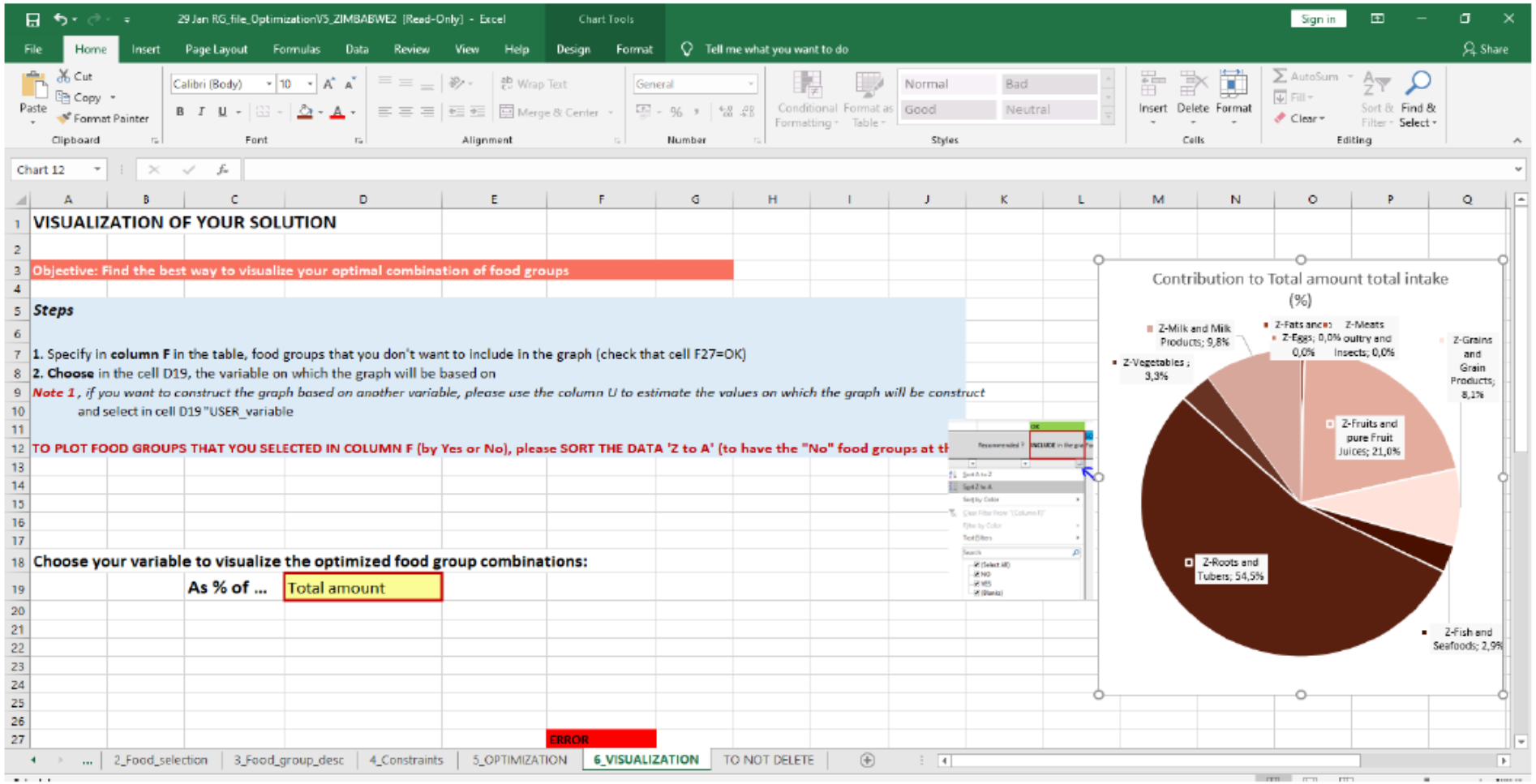
Available linear programming models



optimeal

- Optimeal in Matlab Compiler 7.16 (Blonk Consultants, NL).
- Microdiet System, 1990 (Fletcher, UK)
- spreadsheet programmes provide a simple, free solver function for LP
- Excel “Nutrisurvey” free (Briend, 2003)
- SAS (Version 8.02) + Excel SOLVER developed by Frontline Systems (Gao, 2006)
- LINGO Hyper (10.0, LINDO Systems Inc., USA)
- R 2012 through a GNU Linear Programming Kit + IpSolveAPI package (or “Rglpk”)
- MS Nutrition Excel + Apps (Vieux, 2014, France) -> FAO diet optimisation package for food based dietary guidelines + Diet optimisation on FAO/WHO GIFT platform data (2019)

FAO diet optimisation package for food-based dietary guidelines



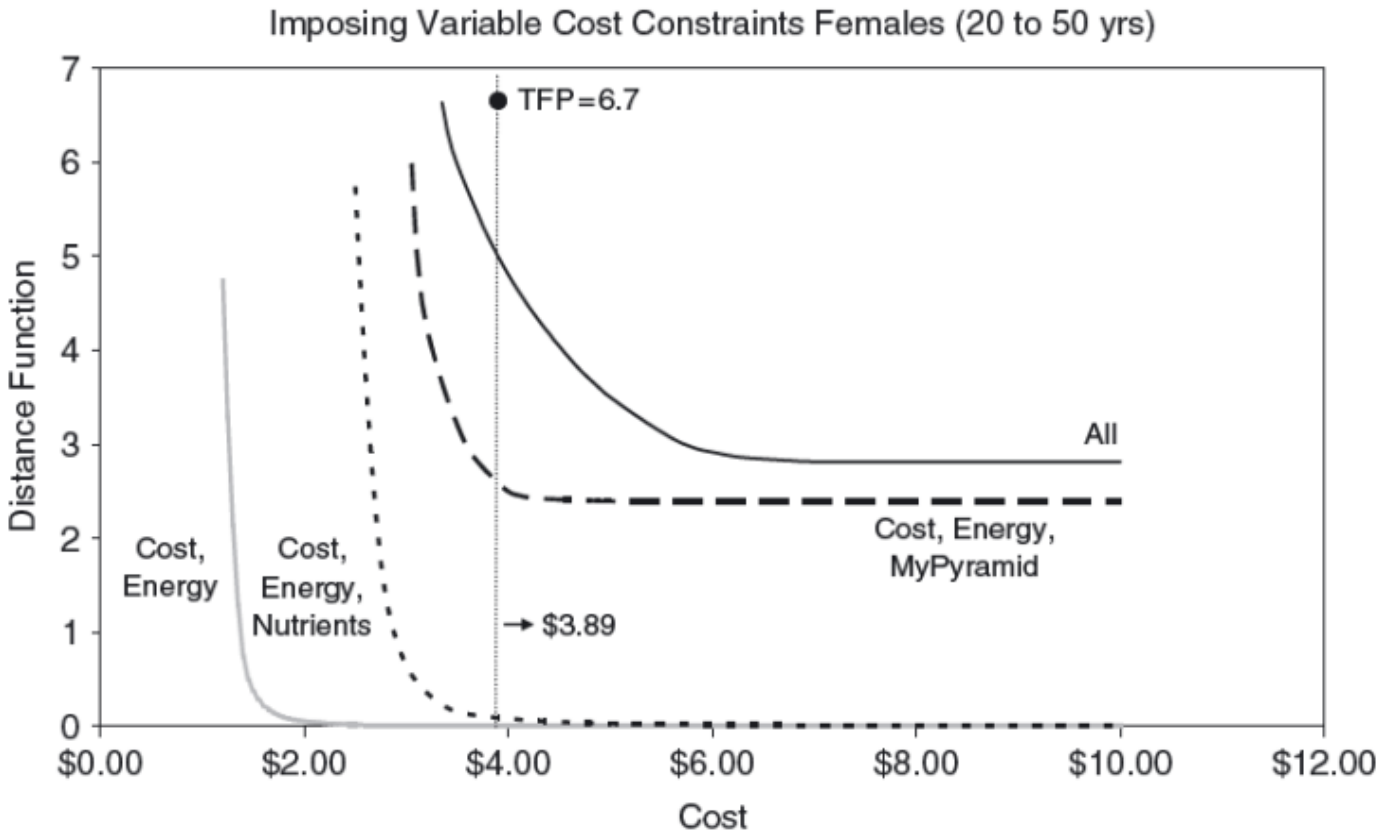
Step 6: user vizualizes the results: **-Optimized amounts per food group**

-Contributions of food groups to optimized nutritional contents

MS Nutrition
La solution quantitative

Thrifty Food Plan USA (since 1975)

The Distance Value of the Optimal Solution, as a Function of the Cost Target, Under Four Scenarios for Additional Nutrition Constraints: (1) Energy, (2) Energy and MyPyramid Categories, (3) Energy and Nutrients, (4) All of the Preceding Constraints



THE JOURNAL OF CONSUMER AFFAIRS

PARKE E. WILDE AND JOSEPH LLOBRERA (2009)

Using the Thrifty Food Plan
to Assess the Cost of a Nutritious Diet

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Sustainability **2015**, *7*, 12837-12855; doi:10.3390/su70912837

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sustainability

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Article

Combining Low Price, Low Climate Impact and High Nutritional Value in One Shopping Basket through Diet Optimization by Linear Programming

Corné van Dooren [1,2,*], Marcelo Tyszler [3], Gerard F. H. Kramer [3] and Harry Aiking [2]

Women: -43% GHGE & - 23% costs

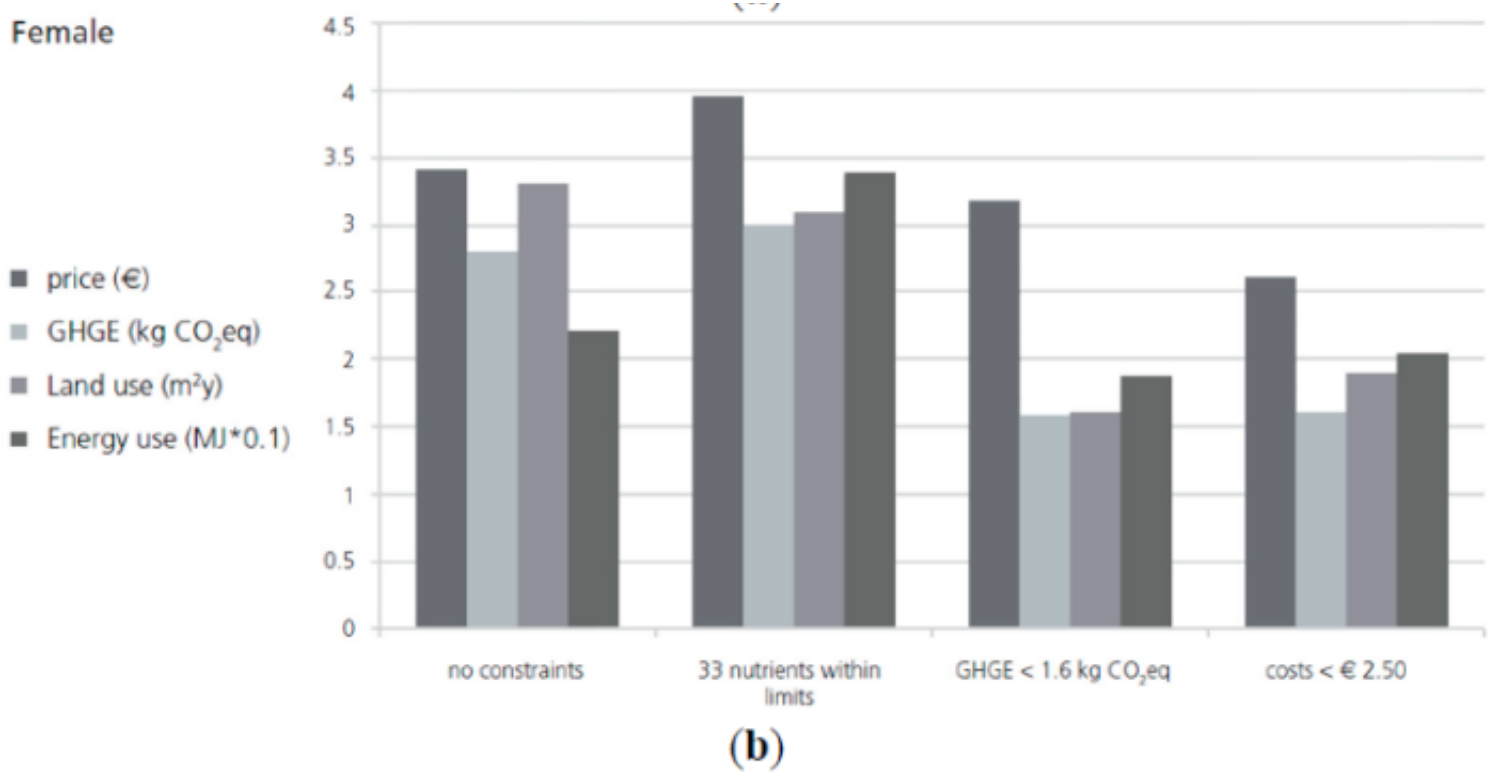

Figure 1. (**a**) Changes in greenhouse gas emissions (GHGE), land use (LU), energy use and price after three subsequent cycles with: (1) 33 nutrients, (2) GHGE, and (3) costs as constraints in linear programming compared to average consumption by male adults in 2007–2010; (**b**) Changes in constraints for female adults.

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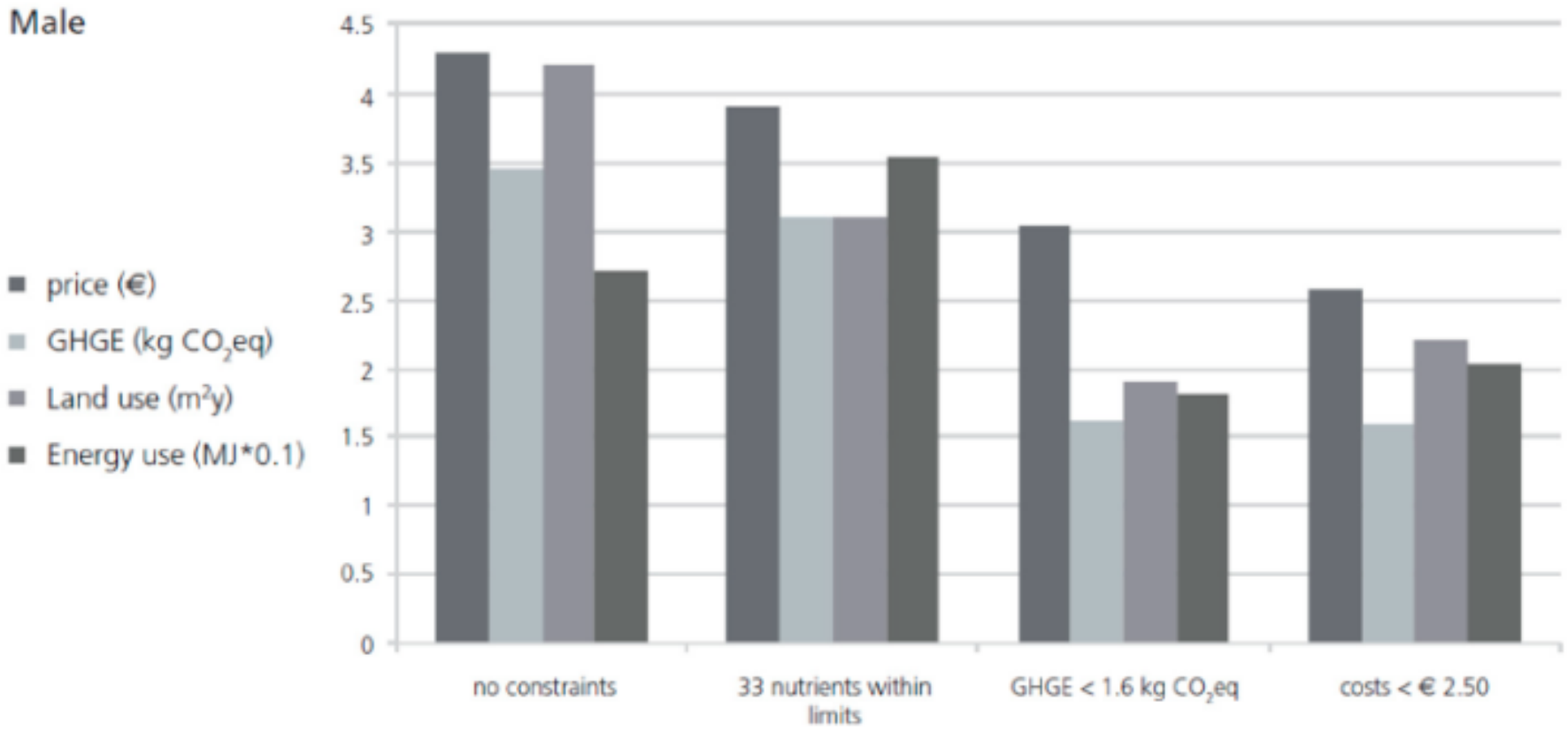
Men: - 54% GHGE & - 40% costs



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(a) Male (Age 31–50)	Weight (g)		
Product Group	Average Diet	Optimized Diet	Difference
Potatoes	99	111	12
Alcoholic drinks	206	0	−206
Non-alcoholic drinks	1252	1443	191
Bread	144	225	81
Eggs	11	0	−11
Fruits	83	200	117
Cakes	42	42	0
Cereals	49	49	0
Vegetables	74	200	126
Spreads (peanut butter, humus, hazelnut paste)	9	30	20
Cheese	32	0	-32
Milk and milk products	317	32	−284
Nuts, seeds and snacks	14	54	40
Legumes	0	125	125
Soy products (soy drink)	0	412	412
Sugar and confectionary	27	27	0
Fats, oils and sauces	49	47	-2
Fish	9	10	2
Meat and meat products	66	7	-59
Miscellaneous [1]	552	0	
Total	**3033**	**3013**	**−1%**

(b) Female (Age 31–50)	Weight (g)		
Food Groups	Average Diet	Optimized Diet	Difference
Potatoes	74	74	0
Alcoholic drinks	30	0	−30
Non-alcoholic drinks	1345	1266	−79
Bread	113	113	0
Eggs	10	10	0
Fruits	102	200	98
Cakes	40	40	0
Cereals	39	39	0
Vegetables	70	200	130
Spreads (peanut butter, humus, hazelnut paste)	6	6	0
Cheese	27	0	−27
Milk and milk products	232	50	−183
Nuts, seeds and snacks	11	49	38
Legumes	0	194	194
Soy products (soy drink)	0	417	417
Sugar and confectionary	25	30	5
Fats, oils and sauces	25	25	0
Fish	1	10	9
Meat and meat products	44	3	−41
Miscellaneous [1]	632	0	
Total	**2827**	**2725**	**−4%**

Int J Life Cycle Assess (2016) 21:688–700
DOI 10.1007/s11367-015-1007-3

LCA OF NUTRITION AND FOOD CONSUMPTION

Defining a nutritionally healthy, environmentally friendly, and culturally acceptable Low Lands Diet

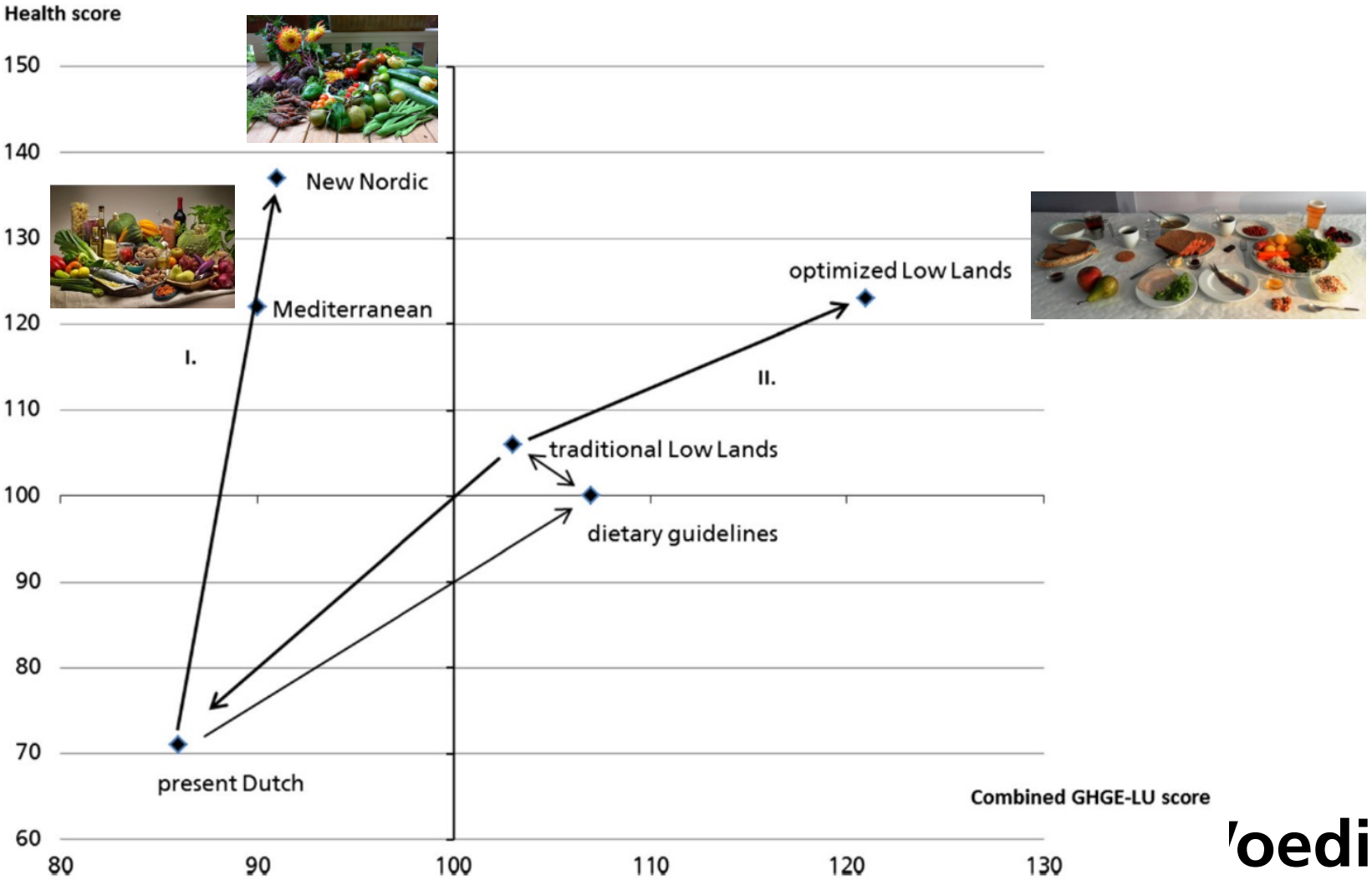
Corné van Dooren[1,2] · Harry Aiking[2]

*"Through applying the method of linear programming,
it is possible to calculate an optimal diet for the Low Lands with a short cultural distance, that is, as healthy as and more sustainable than a transition to more foreign European diets (Mediterranean, New Nordic)."*

Low Lands Diet: historical (1900-1940) & optimised

historical Low Landsdiet	optimized Low Landsdiet
350 g potatoes	350 g potatoes
180 g vegetables (leafy, roots, cabbages)	215 g vegetables (extra lettuce and kale)
145 g fruits (apple, pear, berries)	277 g fruits (extra pear)
18 g legumes	51 g legumes
	24 g nuts
35 ml soup	35 ml soup
210 g rye and wheat bread (6 slices)	210 g rye and wheat bread (6 slices)
30 g rice and 10 g other grain products	10 g other grain products
2 portions porridge incl. 250 ml buttermilk	2 portions porridge incl. 325 ml skimmed milk
150 ml full fat milk	150 ml full fat milk
20 g cheese	no cheese
40 g butter, rapeseed oil, margarine	40 g butter, rapeseed oil, margarine
25 g fish	37 g oily fish
55 g meat (pork, beef and chicken)	48 g meat (pork and chicken)
300 ml coffee, 250 ml tea	300 ml coffee, 250 ml tea
300 ml beer, 6 ml wine	300 ml beer
	300 ml water
32 g extras (sugar, jam, chocolate, syrup, cake)	32 g extras (sugar, jam, chocolate, syrup, cake)

More sustainable than and equal healthy as the Mediterranean and Nordic diets



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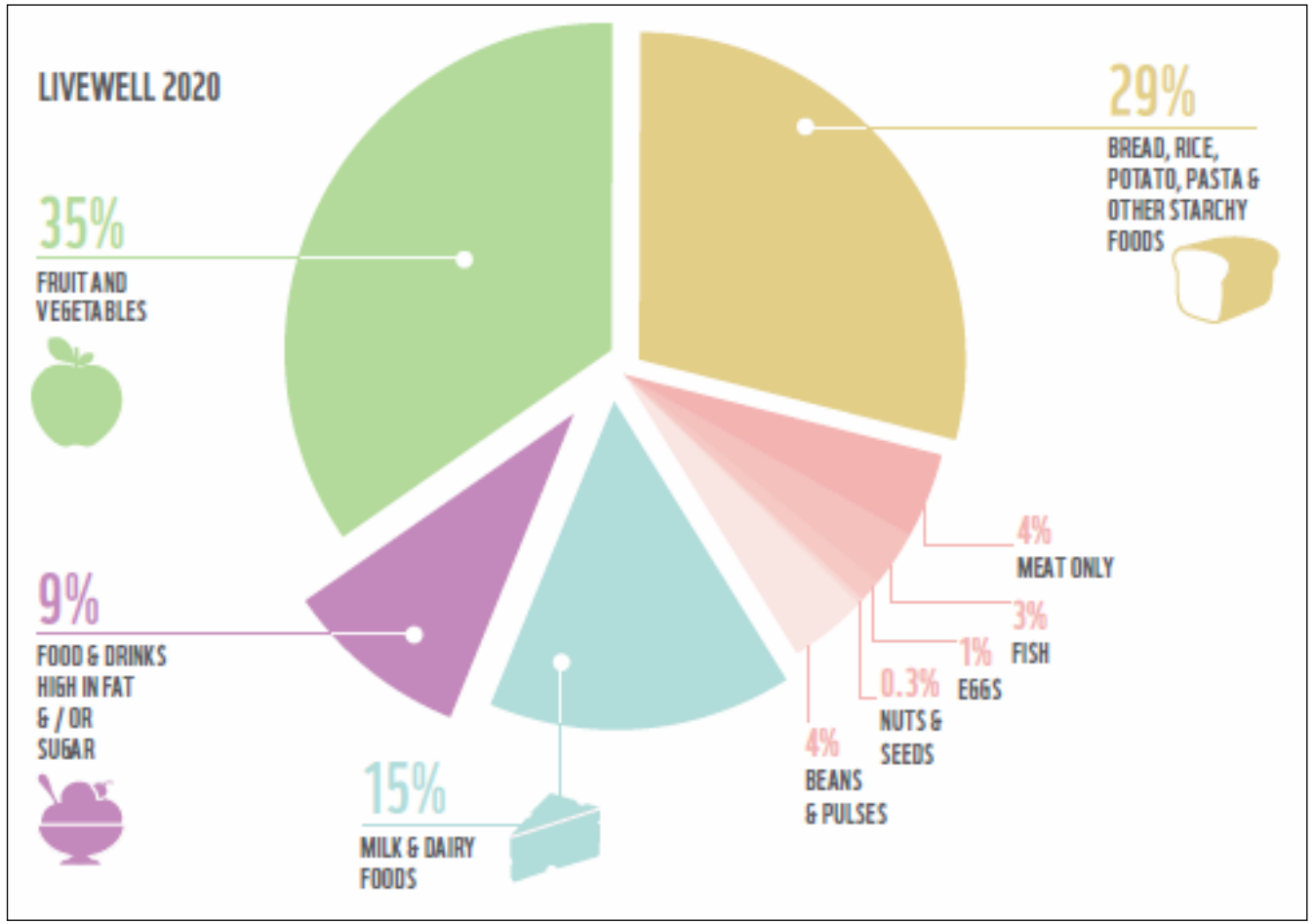
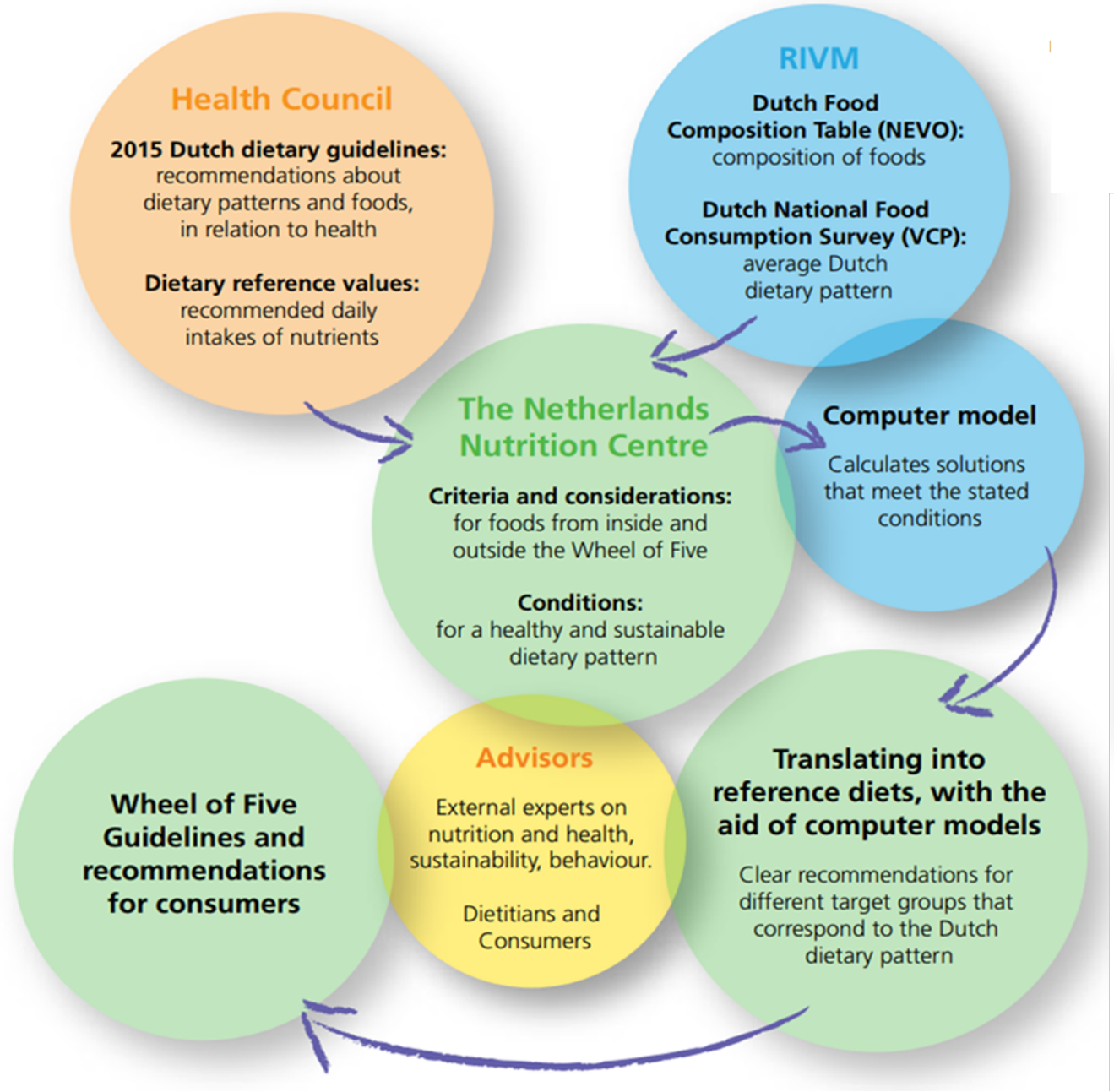
Livewell plate UK (WWF, 2011)

Goal: 25% reduction in greenhouse gas emissions through linear programming



(Macdiarmid J. et al., 2011)
WWF/ Rowett Institute



National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

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Public Health Nutrition: page 1 of 17 doi:10.1017/S1368980019001435

Development of healthy and sustainable food-based dietary guidelines for the Netherlands

Elizabeth Brink[1,*], Caroline van Rossum[2], Astrid Postma-Smeets[1], Annette Stafleu[1], Danielle Wolvers[1], Corné van Dooren[1], Ido Toxopeus[2], Elly Buurma-Rethans[2], Marjolein Geurts[2] and Marga Ocké[2]

[1]The Netherlands Nutrition Centre (Voedingscentrum), PO Box 85700, 2508 CK The Hague, The Netherlands:
[2]National Institute for Public Health and the Environment (RIVM), Bilthoven, The Netherlands

Submitted 13 July 2018: Final revision received 4 March 2019: Accepted 27 March 2019

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Translation to the Wheel of Five

Diet optimisation modelling

Preconditions modelling

- In line with dietary guidelines **AND** dietary reference values from the Health Council
  - Minimal and maximal amounts of food groups and nutrients
- Provides 100% of the essential nutrients
  - Provides on average 85% of kcal
- Sustainable and feasible: maximal amounts of food groups
- Close to the current diet of each target group

- Target groups (age, gender, activity level, preference, ethnicity)

Constraints: on products, not on impacts (GHGE, LU)
Based on environmental impact & feasibility

Table 2 List of food constraints for adults used in the optimisation calculations in the development of food-based dietary guidelines for the Netherlands

Food group	Minimum	Reason for minimum	Maximum	Reason for maximum
Vegetables (g/d)	200	Health*	–	
Fruit (g/d)	200	Health*	–	
Wholegrain cereals (g/d)	90	Health*	–	
Fish (g/week)	100	Health†	125	Environmental impact‖
Legumes (g/week)	65	Health†	135	Feasibility§
Red meat (g/week)	–		Male: 500†,‡ Female: 50th percentile of consumption§	Health†, environmental impact‖
Total meat (g/week)	–		50th percentile of consumption§	Environmental impact‖
Eggs (g/week)	–		150	Health†, environmental impact‖
Nuts (g/d)	15	Health*	25	Feasibility§
Dairy products (g/d)	300	Health†	75th percentile of consumption§	Environmental impact‖

Results of optimisation: large variation between gender and age

	1-3 jaar		4-8 jaar		9 -13 jaar		14-18 jaar		19-30 jaar		31-50 jaar		51-69 jaar		>70 jaar	
	Jongens*	Meisjes*	Jongens*	Meisjes*	Jongens	Meisjes	Jongens	Meisjes*	Mannen	Vrouwen	Mannen	Vrouwen	Mannen	Vrouwen	Mannen	Vrouwen
Groente					272	389	234		200	561	204	700	246	249	235	271
Fruit					200	200	200		200	200	200	200	200	200	200	200
Brood					214	260	254		275	334	271	245	232	136	195	113
Graanproducten					81	0	221		200	9	169	75	125	76	82	132
Aardappelen					163	140	193		147	26	137	0	133	93	127	37
Vis en schaaldieren					18	18	16		15	18	16	18	18	18	18	18
Peulvruchten					19	19	19		19	19	19	19	19	19	19	9
Wit vlees					43	63	32		31	68	11	68	22	13	30	19
Rood vlees					46	13	28		28	8	26	8	41	57	70	57
Ei					21	21	6		19	21	21	21	21	21	21	21
Noten, pitten, zaden					25	25	25		25	25	25	25	22	22	25	15
Melk en melkproducten					258	256	285		277	299	267	300	270	252	303	293
Kaas					64	44	47		23	1	33	0	39	48	61	53
Smeer- en bereidingsvetten					36	26	79		96	22	92	22	80	42	54	32
Dranken					487	1194	554		969	3524	1340	3201	1220	1594	1191	1369

* Geen oplossing.

Tabel 4.4 Resultaten van de optimalisatie naar het Nederlandse voedingspatroon. De hoeveelheden zijn in grammen per dag.

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Recommended daily amounts (women, 19-50 yrs)

grams of vegetables	250
fruit portions	2
slices of brown or whole grain bread	4-5
tablespoons of whole grain products or number of small potatoes	4-5
portions*	1
grams of unsalted nuts	25
dairy portions	2-3
grams of cheese	40
grams of oils and fats	40
litres of liquids	1,5-2

Meets DRV's

* In this segment our advice is to vary between products. **Choose weekly,**

grams of fish	100
tablespoons of legumes	2-3
grams of meat	max. 500
eggs	2-3

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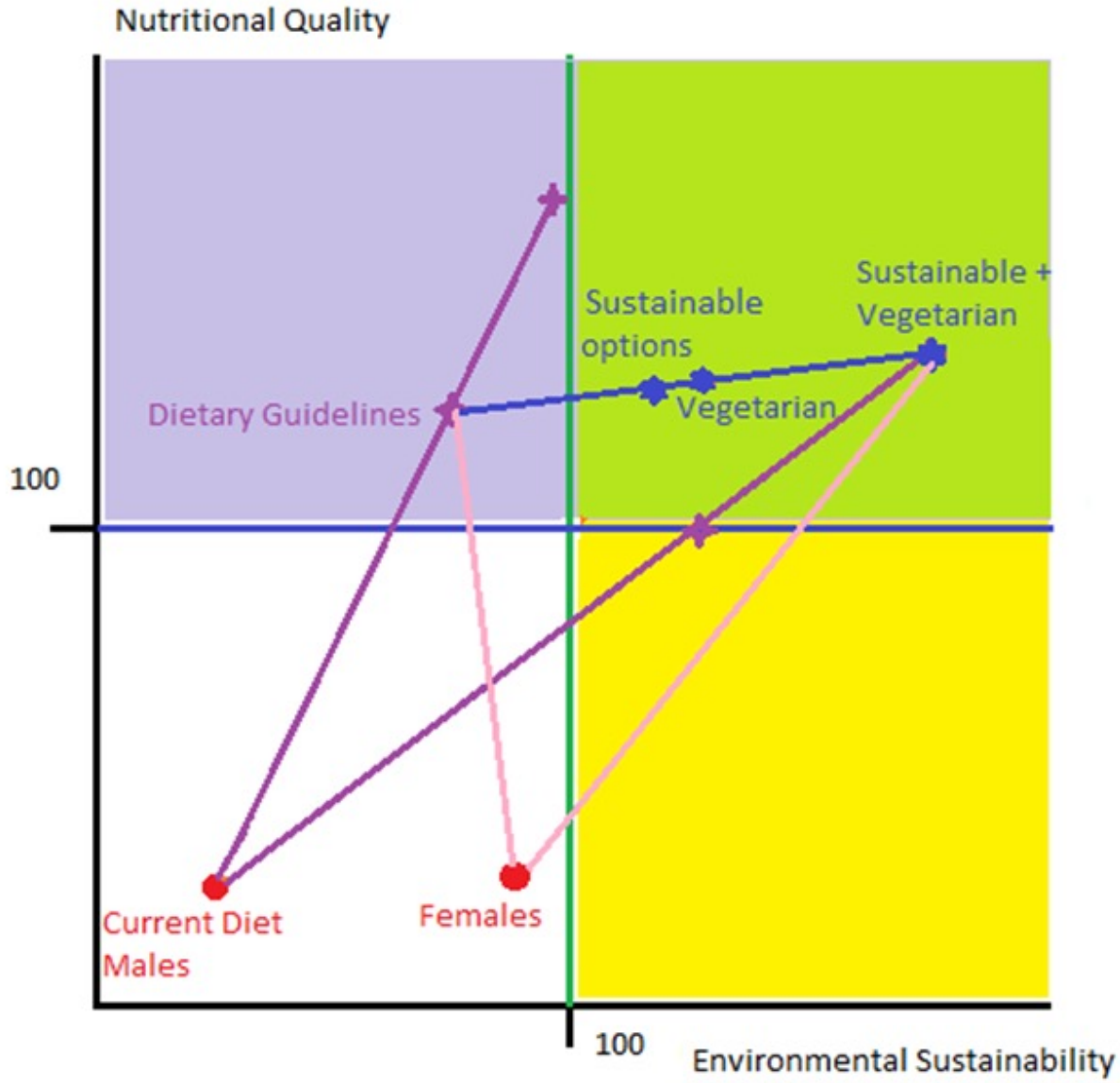
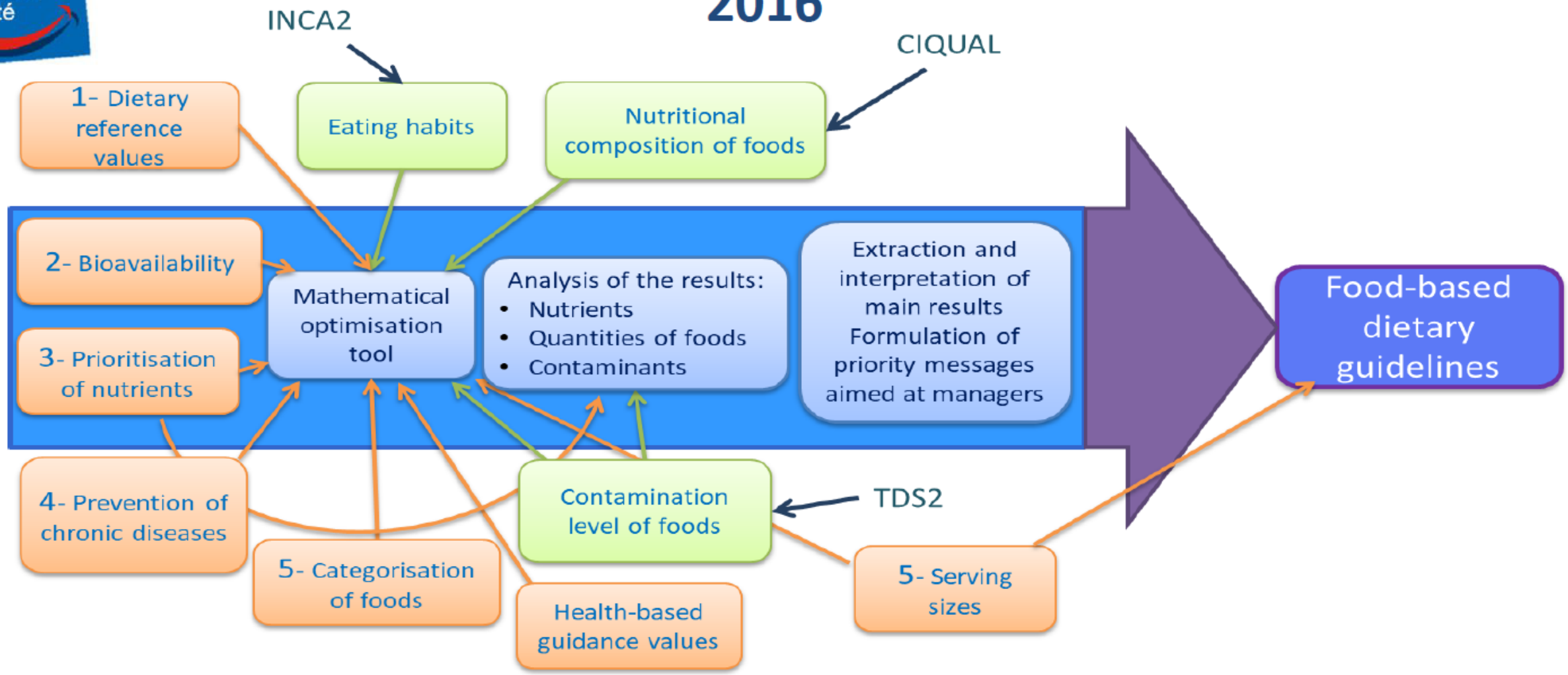
Most options within the scope of the dietary guidelines (blue line) are more environmentally sustainable than the current diet

(van de Kamp et al. 2018; Brink et al. 2016)



French FBDG: Evolution of approaches

2016



+ Global approach

- Dietary patterns not observed → acceptability?

Germany FENS/ DGE (2019):
start update FBDGs with optimisation modelling

- a suitable tool to formulate FBDGs finding trade-offs between conflicting goals and taking several dimensions into account.
- the challenge to compile diverse data that suit the demands of optimisation models.
- individualisation via mathematical optimisation is one perspective of FBDGs to increase consumer acceptance,
- but the application for population-based and individual FBDGs requires more experience and evaluation for further improvements.

Integration of various dimensions in food-based dietary guidelines via mathematical approaches: report of a DGE/FENS Workshop in Bonn, Germany, 23–24 September 2019

Anne Carolin Schäfer[1,2*], Annemarie Schmidt[1], Angela Bechthold[1], Heiner Boeing[3], Bernhard Watzl[4], Nicole Darmon[5], Brecht Devleesschauwer[6,7], Thomas Heckelei[8], Sara Monteiro Pires[9], Perrine Nadaud[10], Corné van Dooren[11] and Florent Vieux[12]

(BJN, 2021)

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EAT Lancet diet: Close to Wheel of Five

Compared to Wheel of Five:

- Less red meat
- More fish
- Less dairy
- Less potatoes

	EAT-Lancet	EAT-lancet range	Schijf van Vijf Man	Schijf van Vijf Vrouw	Schijf van Vijf Range
	Grammen per dag				
Volkoren graanproducten*	232	0-60 en%	358, incl. brood	271, incl. brood	
Aardappelen	50	0-100	158	158	
Groente	300	200-600	250	250	
Fruit	200	100-300	200	200	
Zuivelproducten	250	0-500	415, incl. kaas	415, incl. kaas	340-490
Rood vlees	14	0-28	43	43	0-43**
Wit vlees	29	0-58	29	29	0-29**
Eieren	13	0-25	18	18	18-25**
Vis	28	0-100	14	14	14
Peulvruchten	75	0-100	19	19	19-38**
Noten	50	0-75	25	25	25-32**
Toegevoegd vet	40 onverzadigd 11,8 verzadigd	20-80 0-11,8	65 (smeer- en bereidingsvet)	40 (smeer- en bereidingsvet)	
Toegevoegd suiker	31	0-31	-	-	

Menu of Tomorrow: EAT- Lancet improved (LP)

(Kramer & Blonk, 2015; Natuur & Milieu)

HET MENU VAN GISTEREN 2010

1.5 glazen melk per dag
2 plakken kaas per dag
1,5 handje noten per week
5 tot 6 dagen per week vlees
2 scheppen groente per dag
1 keer peulvruchten per maand

HET MENU VAN MORGEN 2030

1 glas melk per dag
1 plak kaas per dag
1,5 handje ongezouten noten per dag
2 tot 3 keer per week vlees
5 scheppen groente per dag
2 keer peulvruchten per week

MEER

Duurzame vis

Peulvruchten

Peer, kiwi en citrusvruchten

(Volkoren) brood

Noten & zaden

Vegetarische producten
op basis van soja

Groenten
wortel, prei, ui, bieten, spruitjes, boerenkool, erwtjes, spinazie

Zilvervliesrijst

MINDER

Vlees

Aardbei, druiven, ananas en meloen

Melk / andere zuivelproducten

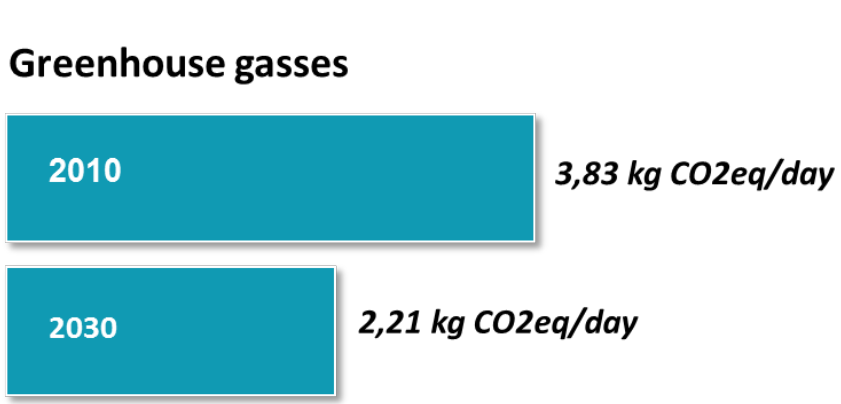
Dranken
wijn, frisdrank, vruchtendsap

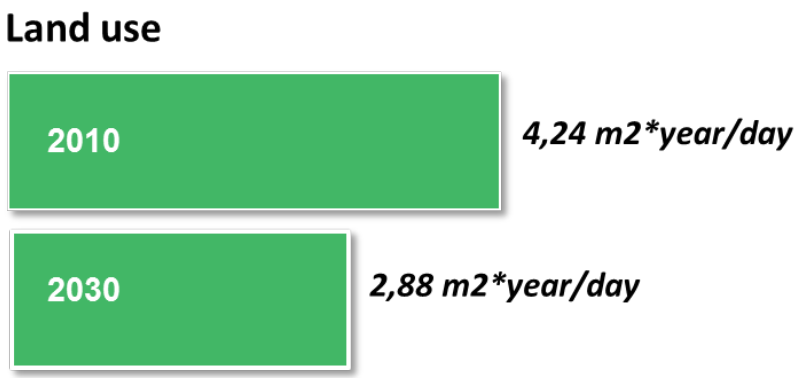
Kaas

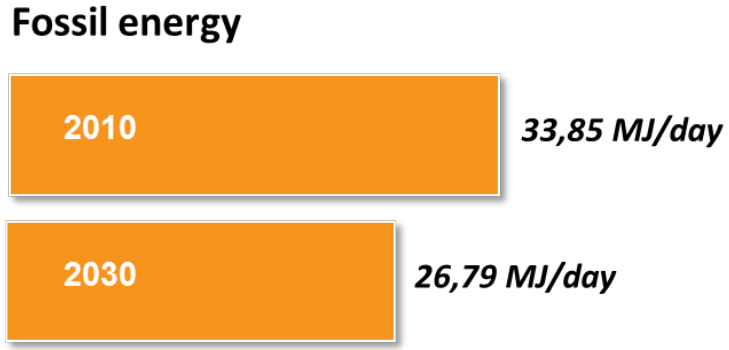
(Kas)groenten
champignons, broccoli, paprika, tomaat, courgette

Menu of Tomorrow: multiple constraints

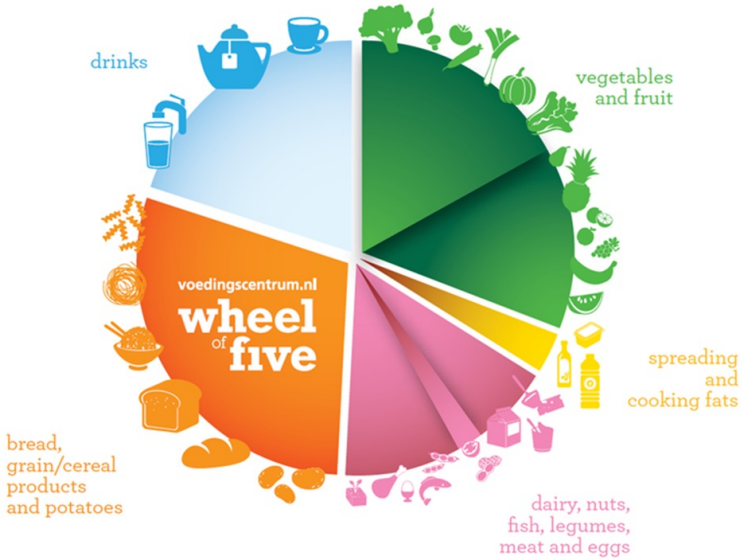
(Kramer & Blonk, 2015 not published)

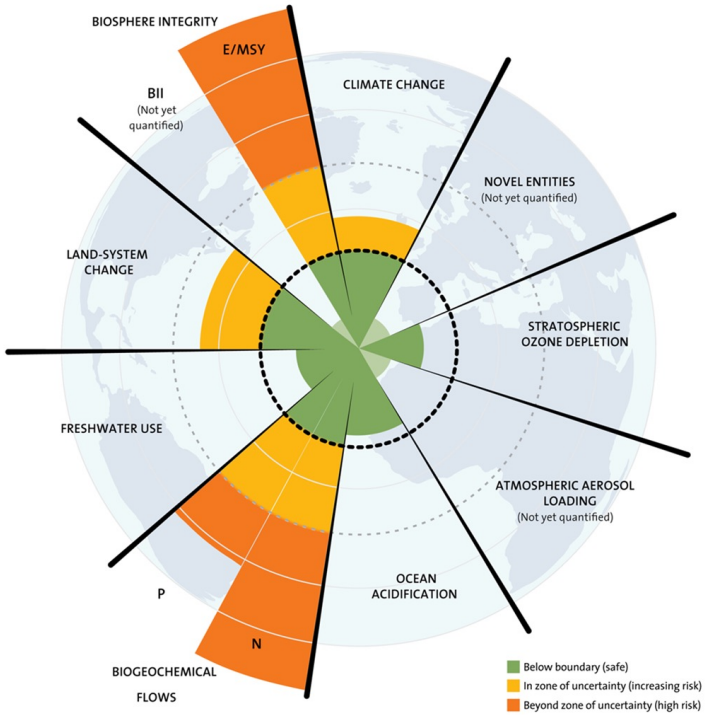


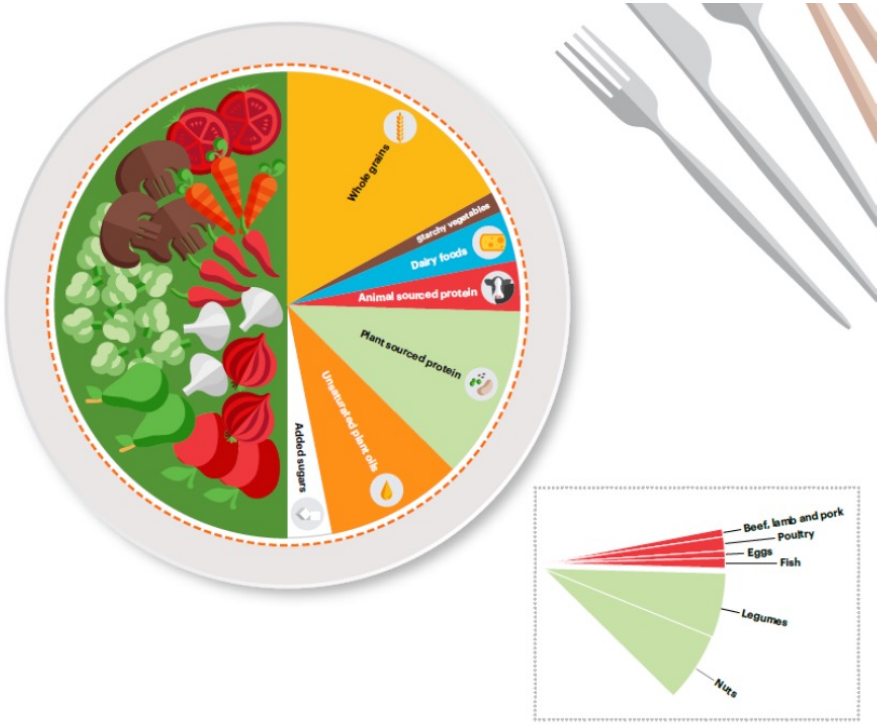




Future: sustainability more integrated + more constraints = planetary boundaries







EAT Lancet (2019)

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