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FAO METHODOLOGY FOR THE MEASUREMENT OF FOOD DEPRIVATION

Updating the minimum dietary energy requirements

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1. INTRODUCTION

The FAO measure of food deprivation, referred as the prevalence of undernourishment, is based on a comparison of usual food consumption expressed in terms of dietary energy (kcal) with minimum energy requirement norms. The part of the population with food consumption below the minimum energy requirement is considered underfed or food deprived.

FAO has been traditionally preparing estimates referring to the prevalence of food deprivation in connection with its World Food Survey reports, the last being The Sixth World Food Survey (FAO, 1996). The principal aim of the estimates in this context has been to provide information on the broad dimension of the hunger problem in the developing world. In fact, although the estimates have been worked out on a country-by-country basis, only the global and regional aggregates have been published. Furthermore, the focus has been on the long-term trends as the World Food Surveys were issued between periods of roughly ten years. However, monitoring needs have changed following recent major international Summits. The World Food Summit in 1996 fixed a hunger reduction target to be reached by 2015. The Millennium Declaration in 2000 integrated hunger and poverty reduction in one single goal, specifically as the first of the Millennium Development Goals.

Millennium Development Goal on hunger targets to halve, between 1990 and 2015, the proportion of people who suffer from hunger and is specified as Indicator 1.9:

“Proportion of population below minimum level of dietary energy consumption “

For the purpose of monitoring progress towards the target of halving the number of undernourished, the need had arisen to regularly up-date such estimates at the global as well as country level. FAO has been undertaking this task in its annual report on “The State of Food Insecurity in the World” (SOFI), which was first issued in 1999. The estimates cover 106 countries published in SOFI.

The prevalence of undernourishment published in SOFI 2008 have updated the parameter on minimum dietary energy requirements (MDER) used in the FAO methodology based on the report of a Joint FAO/ WHO/ UNU Expert Consultation on human energy requirements (http://www.fao.org/docrep/007/y5686e/y5686e00.htm) released in 2004 and WHO updated

Body Mass Index (BMI[1]) reference tables released in April 2006 (http://www.who.int/childgrowth/standards/bmi_for_age/en/index.html) for children aged less than five years and BMI reference tables released in 2007 (http://www.who.int/growthref/who2007_bmi_for_age/en/index.html) for children and adolescents from 5 to 19 years old.

In the following sections the basic methodological framework, the data sources and the procedures used by FAO for deriving the country estimates are described. The meaning and significance of the resulting estimates of prevalence of undernourishment are discussed. Then, the estimations at sub-national levels are also presented.

2. METHODOLOGICAL FRAMEWORK

The estimate of the proportion of the population below minimum level of dietary energy consumption has been defined within a probability distribution framework:

$$P(U) = P(x < r_L) = \int_{x<r_L} f(x)\,dx = F_x(r_L)$$

where:

P(U) is the proportion of undernourished in total population

(x) refers to the dietary energy consumption

$\mathbf{r_L}$ is a cut-off point reflecting the minimum energy requirement

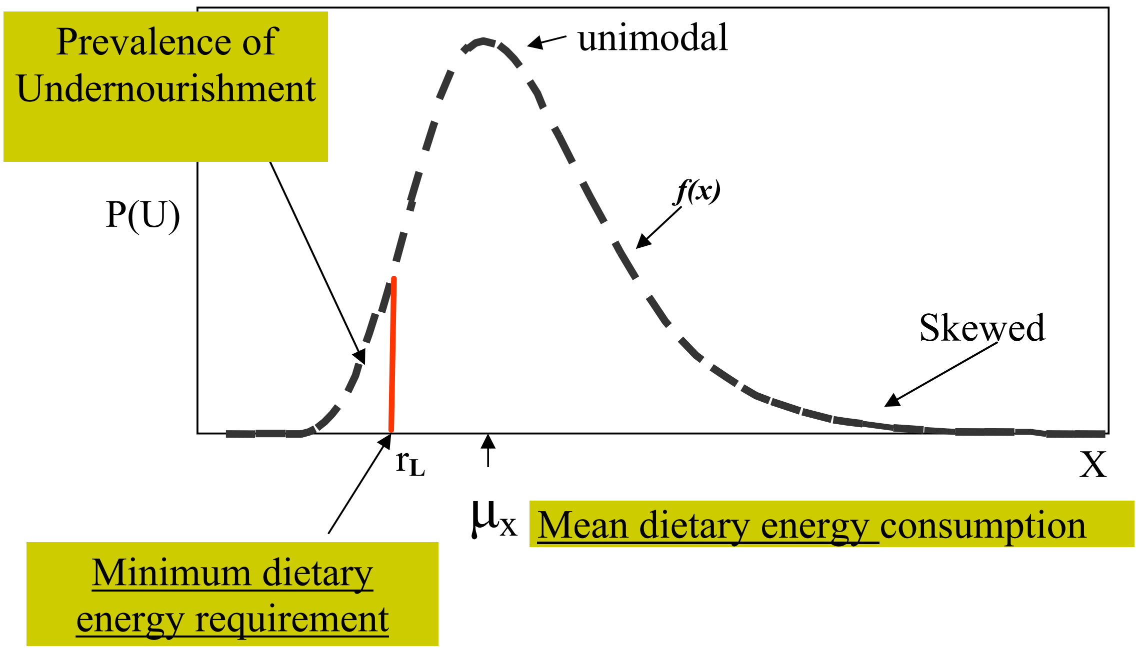
f(x) is the density function of dietary energy consumption

$\mathbf{F_x}$ is the cumulative distribution function of dietary energy consumption

The next paragraphs discuss the estimation of **f(x)** and $\mathbf{r_L}$ and the graph below illustrates the methodological framework for the estimation procedures of the proportion of population undernourished, i.e. prevalence of undernourishment.

[1] The BMI refers to weight (kg) divided by height² (m).

Theoretical distribution of dietary energy consumption



In the graph the curve **f(x)** depicts the proportion of the population corresponding to different per caput dietary energy consumption levels **(x)** represented by the horizontal line. The area under the curve up to the minimum energy requirement which is a cut-off point in the curve, $\mathbf{r_L}$, represents the proportion of the population undernourished, i.e. prevalence of undernourishment.

3. ESTIMATION PROCEDURES

The density function, **f(x)**, **of dietary energy consumption** is assumed to be lognormal so that the parameters μ_x and σ_x^2 can be estimated on the basis of the mean, $\bar{x}$, and the coefficient of variation, **CV(x)**. A summarised description of the procedure for calculating the prevalence of undernourishment on the basis of $\bar{x}$, **CV(x)** and $\mathbf{r_L}$ applied to an hypothetical country is given below.

3.1 Estimation of the mean and coefficient of variation of the density function f(x) of dietary energy consumption

3.1.1 Estimation of the mean, $\bar{x}$

There are two options for estimating the mean $\bar{x}$: using Food Balance Sheet (FBS) data or Household Budget Survey (HBS) data. The first can be used to prepare annual estimates for monitoring progress in food security for the country as a whole. The second one allows the derivation of both national and sub-national estimates. The latter estimates cannot be prepared on a yearly basis, as they depend on the survey frequency, in general ranging from 5 to 10 years.

The estimations of the mean of dietary energy consumption for both options, FBS and HBS, are illustrated below

a) Dietary energy consumption from the Food Balance Sheets (FBS)

The mean is represented by the daily Dietary Energy Supply per person (**DES**) which refers to the food available for human consumption during the course of the reference period, expressed in terms of energy (kcal/person/day). The estimate is derived from the Food Balance Sheets compiled using data on the production (**PROD**) and trade (**IMP**orts and **EXP**orts) of food commodities. Using these data and the available information on stock changes (**STCH**), losses between the levels at which production is recorded and the household (**WASTE)** and types of utilization (**SEED**, **FEED**, **FOOD**, inputs for **PROC**essing derived products and **OTHER** uses) a supply/utilization account is prepared for each commodity in quantity terms. The food component, which is usually derived as a balancing item, refers to the total amount of the commodity available for human consumption during the year. The DES is obtained by aggregating the food component of all commodities after conversion into dietary energy values using the corresponding energy factors. The table below presents the standard Food Balance Sheet for the hypothetical country in 1999-2001.

The DES per person per day of 2414 (kcal) shown in the first row of the last column of the table 1 is the estimate of the mean $\bar{x}$ from FBS data for the hypothetical country, i.e.:

$$\bar{x} = \mathbf{2414}$$

Table 1. The Standard FBS for hypothetical country, 1999-2001

	PROD	+ IMP	+ STCH	- EXP	- FEED	- SEED	- PROC	WASTE	- OTHER	= FOOD	DES CALORIES PER PERSON / DAY (*)
	....1000 MT / YEAR....										
Grand Total											**2414**
Cereals (excl. Beer)	19973.7	1116.5	-355.7	6673.9	5211.8	434.7	407.5	969.4	9.7	7027.8	1114.2
Starchy Roots	16956.2	133.8	-1053.9	13525.9	0.4	0.9	143.7	1350.1	3.7	1011.4	45.2
Sugar crops	53406.6		-1333.3	0.3			43698.3	2753.7		5621.0	73.0
Sugar & Sweeteners	5267.7	11.3	-136.6	3360.6					13.0	1776.6	283.2
Pulses	269.5	5.7		37.9		21.9		8.2		207.3	31.5
Treenuts	54.0	2.2		15.8						40.5	6.5
Oil crops	2337.2	873.5	-198.7	38.5	1.0	14.3	1735.2	135.9		1087.5	100.1
Vegetable Oils	819.9	66.3	-149.9	116.5					272.8	348.7	137.9
Vegetables	2753.0	25.3		372.1			0.0	245.7		2163.9	26.8
Fruits (excl. Wine)	7270.5	55.9	0.2	1173.2			14.5	566.7		5574.7	114.4
Stimulants	78.1	21.4	-6.7	64.6						28.5	0.9
Spices	67.1	7.2		20.9				1.9		51.6	6.9
Alcoholic Beverages	2114.9	28.4		78.9					24.0	2040.4	163.4
Honey	3.0	0.2		1.6						1.6	0.2
Meat	1902.5	3.3		271.6				20.7		1614.8	150.9
Offals	75.7	2.8		0.4						77.7	3.8
Animal Fats	31.8	19.1		0.7					5.6	44.6	15.6
Milk (excl. Butter)	409.4	1095.4		81.1				12.3	12.0	1400.1	32.1
Eggs	812.0	1.3		6.8		137.4		40.6		628.4	42.6
Fish, Seafood	3458.0	532.1	1.7	809.3	1185.9					1996.5	62.2
Aquatic Products	30.1	0.5		14.5						16.1	0.2
Miscellaneous											2.1

(*) Food quantities converted into energy values and divided by total population and by 365 days.

b) Dietary energy consumption from Household Budget Survey (HBS)

This option requires the conversion of quantities of the different food items consumed by the household members into dietary energy values. The food items quantity data are usually collected through household budget surveys using samples with national coverage, which allow the estimation of means at the national level and sub-national levels such as geographic areas and socio-economic population groupings.

3.1.2 Estimation of the coefficient of variation, CV(*x*)

The **CV(*x*)** is the coefficient of variation of the daily per person dietary energy consumption and is formulated as follows:

$$CV(x) = \sqrt{CV^2(x \mid v) + CV^2(x \mid r)}$$

Where

CV(*x*|*v*) is the coefficient of variation of the daily per person dietary energy consumption due to per person daily income **(*v*);** and

CV(*x*|*r*) is the coefficient of variation of the daily per person dietary energy consumption due to energy requirement **(*r*)**.

CV(*x*|*r*) is considered a fixed component and is estimated to correspond to about 0.20. **CV(x|v)** is however estimated on the basis of food consumption data collected in the HBS.

CV(x|v) is estimated using the following formula:

$$\mathbf{CV(x|v) = \sigma\,(x|v) / \mu(x)\,.}$$

Where

σ (x|v) is the standard deviation of the weighted daily per person dietary energy consumption by income deciles distribution and is derived from the formula:

$$\sigma(x \mid v) = \sqrt{\left[\sum_{j=1}^{k} f_j\,(x \mid v)_j^2 - \left(\sum_{j=1}^{k} f_j\,(x \mid v)_j\right)^2 / n\right] / (n-1)}$$

μ(x) is the weighted average daily per person dietary energy consumption by income deciles distribution and is derived from the formula:

$$\mu(x) = \sum_{j=1}^{k} f_j\,(x \mid v)_j \,/\, n$$

k is 10 - the number of income deciles;

f_j is the number of persons in the sampled households of the ***j***th income class;

$(x|v)_j$ is the average daily per person dietary energy consumption of the ***j***th income class; and

n is number of persons in the household income and expenditure survey.

In many cases, total expenditure data are used as a proxy of income data because the latter is not available or wrongly reported at the collection stage.

Thus, the data required for estimating **CV(x|v)** are the averages daily per person dietary energy consumption and the number of persons of the population in each household income deciles. Note that the number of persons in the sampled households has to be expanded to the total population using the sampling and expansion weights. Table 2 below presents the number of persons in the sampled households expanded to the total population and the average daily per person energy consumption by deciles of household per person income from a National HBS conducted in the hypothetical country.

Table 2. Population and average daily dietary energy consumption per person by household income deciles

Deciles of household daily per person income	Population using sampling and expansion weights	Average dietary energy consumption (kcal per person/day)
1	7,143,302	1552
2	5,355,047	1992
3	4,651,270	2096
4	3,301,225	2234
5	3,047,432	2411
6	2,448,956	2607
7	2,109,798	2746
8	1,551,819	2893
9	1,278,544	3069
10	1,019,496	3397
	31,906,889	**2203**

Using the data from the above table,

$\mu(x) = 2203$ and $\sigma(x|v) = 489$

Thus,

$$\mathbf{CV(x|v) = \sigma(x|v) / \mu(x) = 489 / 2203 = 0.222}$$

Hence, given that **CV(*x*|*r*)** corresponds to 0.20, the coefficient of variation **CV(*x*)** of the daily per person dietary energy consumption from HBS data is estimated as

$$CV(x) = \sqrt{0.222^2 + 0.20^2} = 0.30$$

According to the sample size and design, the **CV(*x*)** estimates can also be estimated for geographic areas and socio-economic population groupings.

3.2 Estimation of the minimum dietary energy requirement (cut-off point), $\mathbf{r_L}$

The procedure for estimating the minimum dietary energy requirement (MDER) by sex and age group begins with the specification of the reference body weight. After specifying the reference body weight the procedure for arriving at the corresponding energy requirement differs among population groups of different sex and age. Therefore the procedure for deriving the reference body weight for attained-height is handled first, followed by two separate subsections dealing with the derivation of MDER for the various sex and age population groups and lastly a fourth subsection dealing with the derivation of the overall minimum daily per person energy requirement. MDER can also be estimated for geographic and socioeconomic population groupings, using available data on attained-height, sex and age of the household sampled population.

3.2.1 Reference body- weight

The reference body weights by sex and age groups are based on the available weight-for-height in the Body Mass Index (BMI) reference tables published by the World Health Organization (WHO). Thus given an estimate of the actual attained-height the acceptable weight corresponding to this height is derived from these tables.

For **children below age 10** the reference body weight is fixed at the **median** of the range of weight-for-height given by the BMI reference tables (WHO, 2006).

For **children and adolescents** of age 10 and above, the reference body weight is estimated on the basis of the **fifth** percentile of the distribution of the BMI (WHO 2007) and for **adults** the **fifth** percentile of the distribution of the BMI (WHO, 1995).

The actual attained-heights by sex and age used are those estimated by national anthropometric studies. The attained-height figures for the hypothetical country are given in Table 3 below.

Table 3: Average heights by age and sex

Actual height in cm					
Age (years)	Male	Female	Age (years)	Male	Female
0	66.5	61.5	10	128.8	129.0
1	73.5	71.5	11	133.5	135.7
2	81.5	79.5	12	138.6	142.4
3	87.5	85.5	13	144.3	146.8
4	96.5	95.5	14	150.9	149.1
5	102.5	100.5	15	157.6	151.0
6	108.5	108.5	16	162.8	152.9
7	113.5	113.5	17	165.0	153.8
8	118.5	117.5	18 +	166.0	154.4
9	122.5	122.5			

3.2.2 Minimum dietary energy requirements for children and adolescents below 18

The minimum dietary energy requirement per person for children is obtained by multiplying the reference body weight for attained-heights as in the BMI reference tables by the recommended energy requirement per kilogram of body weight for each sex and age population group. The energy requirements per kilogram of body weight are based on the recommendations of the report of a Joint FAO/WHO/UNU Expert Consultation on human energy requirements (FAO/WHO/UNU, 2004).

3.2.3 Minimum dietary energy requirements for adults

The minimum dietary energy requirements per person for adults and adolescents are derived by first estimating the Basic Metabolic Rate **(BMR)** on the basis of the reference body weight and using the sex and age specific regression parameters of the Schofield equations (James and Schofield, 1990). The Schofield equations were endorsed in the 2004 report on human energy requirements.

Then, the minimum energy requirements are derived by multiplying BMR by sex specific Physical Activity Level factors.

3.2.4 The overall daily per person minimum dietary energy requirement

The overall daily minimum dietary energy requirement per person, which is used as the cut-off point, $\mathbf{r_L}$, for estimating the prevalence of undernourishment, is derived by aggregating the sex-age requirements weighted by the proportion of each sex and age group in the total population.

Finally, a pregnancy allowance (**PA**) in per person terms for the whole population is added to the overall requirement. The PA is estimated by multiplying the birth rate by 210 kilo-calories, assuming an estimated daily requirement of 280 kilo-calories during pregnancy over 75 per cent of the year.

The estimated country birth rate for 1999-2001 is 26 per thousand. Thus, the overall daily minimum dietary energy requirement per person is derived as follows:

$$\mathbf{r_L = \Sigma_{ij} (MER_{ij} * P_{ij}) + PA = 1673 + 7 = 1680 \text{ kcal/day}}$$

Where :

MER = daily minimum dietary energy requirement per person

$\mathbf{P_{ij}}$ = proportion of each sex and age group in the total population

PA = pregnancy allowance

i = age group

j = sex

Details for computing this value are given in the annex.

3.3. Estimation of the proportion and number of undernourished using FBS data

The density function of dietary energy consumption, **f(x)**, as indicated previously, is assumed lognormal with parameters μ_x and σ_x^2. These parameters are estimated using the derived values of the mean $\bar{x}$, 2414 Kcals per person per day using FBS data, and coefficient of variation ***CV*(*x*)** of the dietary energy consumption from HBS data as follows:

$$\sigma_x = [\log_e (CV^2(x) + 1)]^{0.5} = [\log_e (0.30^2 + 1)]^{0.5} = 0.2936$$

and

$$\mu_x = \log_e \bar{x} - \sigma^2 / 2 = \log_e 2414 - 0.2936^2 / 2 = 7.74594$$

The proportion of population below $\mathbf{r_L}$ is then evaluated using the standard normal cumulative distribution and is as follows:

$$\mathbf{\Phi\ [\ (log_e\ r_L - \mu)\ /\ \sigma)\ ]\ =\ \Phi\ [\ (log_e\ 1680 - 7.74594)\ /\ 0.2936)\ ]\ =\ \Phi\ [\ -\ 1.0878\ ]\ =\ 0.138}$$

Where:

$\mathbf{\Phi}$ = standard normal cumulative distribution.

Thus,

the percentage of the population undernourished = 13.8 or 14.

As the total population of the hypothetical country is 31.9 million, the number of undernourished is obtained as follows:

Number of undernourished = 31.9 * 0.138 = 4.4 million.

3.4. Estimation of the proportion and number of undernourished using HBS data

The density function of dietary energy consumption, **f(x)**, as indicated previously, is assumed to be lognormal with parameters $\boldsymbol{\mu_x}$ and $\boldsymbol{\sigma_x^2}$. These parameters are estimated using the derived values of the mean $\bar{x}$ **,** 2203 Kcals per person per day and the coefficient of variation ***CV*(*x*)** of the dietary energy consumption, both estimated from HBS data as follows:

$$\boldsymbol{\sigma_x\ =\ [\ \log_e (CV^2(x) + 1)\ ]^{0.5}\ =\ [\ \log_e (0.30^2 + 1)\ ]^{0.5}\ =\ 0.2936}$$

and

$$\boldsymbol{\mu_x\ =\ \log_e \bar{x}\ - \sigma^2/ 2 = \log_e 2203 - 0.2936^2 / 2\ =\ 7.6545.}$$

The proportion of population below $\mathbf{r_L}$ is then evaluated using the standard normal cumulative distribution as follows:

$$\mathbf{\Phi\ [\ (log_e\ r_L - \mu)\ /\ \sigma)\ ]\ =\ \Phi\ [\ (log_e\ 1680 - 7.6545)\ /\ 0.2936)\ ]\ =\ \Phi\ [\ -\ 0.7763\ ]\ =\ 0.219}$$

Where:

$\mathbf{\Phi}$ = standard normal cumulative distribution.

Thus,

the percentage of the population undernourished = 21.9 or 22.

As the total population of the hypothetical country is 31.9 million, the number of undernourished is obtained as follows:

Number of undernourished = 31.9 * 0.219 = 7.0 million.

4. MEANING, SIGNIFICANCE AND ADVANTAGES OF THE ESTIMATES OF THE PREVALENCE OF UNDERNOURISHMENT

The data and approximations used to estimate the parameters of the density function of dietary energy consumption and the cut-off point have implications on the precise meaning and significance of the resulting estimate of the prevalence of food deprivation. These are discussed below.

4.1 *Concept of food consumption*

The daily per person dietary energy supply (DES) refers to food available to be acquired by the population.

The daily per person dietary energy consumption (DEC) refers to food acquired by the households to be consumed by the household members.

4.2 *Time reference*

When Food Balance Sheet data are used, the daily per person DES taken as the mean of **f(x)** corresponds to a three-year rather than annual average in order to even out the effect of errors in the annual food stocks data used in preparing the food balance sheets. On the other hand, the daily per person food consumption from HBS refer to a one-year average period. Furthermore, for the purpose of deriving the **CV(x|v)**, only HBS data grouped according to income or total expenditure deciles are used thus removing the effect of seasonal and other short-term variation that the household level data are subject to. As a consequence of these, the estimate refers to the average condition during the given one or three-year period and the effect of seasonal and other short-term variations in food availability are not considered.

4.3 *Use of concept of minimum dietary energy requirement as cut-off point*

The cut-off point is derived by aggregating the sex-age specific minimum dietary energy requirements using the proportion of the population in the different sex-age groups as weights. The specific minimum dietary energy requirements for sex and age population groups are based on the total energy expenditure corresponding to the minimum acceptable limit of the range of body-weight for attained-height and the sedentary physical activity. This approach of arriving at the cut-off point might give the impression that food deprivation is operationally defined as the state of having a food consumption level that is below that needed by an average individual for maintaining minimum acceptable body-weight and performing light sedentary. This is however, strictly speaking, not so. The minimal approach in establishing the cut-off point is a consequence of the consideration that, due to the effect of correlation between energy intake and requirement, the individuals with consumption falling within the range of variation of requirement are likely to be close to, if not exactly, matching their requirements. In other words, their risk of food shortfall or excess is negligible if not exactly zero.

4.4 *Advantages of the use of food consumption estimates from Food Balance Sheets*

The procedure of using the daily per person DES derived from the food balance has some advantages as indicated below.

- The FAO daily per person DES database, which covers practically all countries of the world, is regularly revised and up-dated in connection with FAO's continuous work programme on supply and utilization accounts and food balance sheets. As a result, the database represents a readily available source of information for the assessment and monitoring of the prevalence of food deprivation at the global, regional and country levels.

- The linkage of the daily per person DES with a measure of inequality within a probability framework provides a mechanism for assessing the effect of short-term changes in aggregate food availability as well as its components (production, import, etc.) on the distribution of dietary energy consumption and hence the prevalence of food deprivation. In addition, the use of a probability model – such as the lognormal function – facilitates the assessment of expected changes in the prevalence of food deprivation as a result of the combined effect of food supply increase and inequality reduction, as illustrated in the table below.

Mean Food Consumption (kcal/caput/day)	Food deprivation (%) at MDER of 1680 kilo-calories different levels of food consumption and inequality (CV = coefficient of variation)			
	0.20	0.24	0.29	0.35
1700	52	53	54	55
2040	19	24	29	34
2450	4	7	12	17
2940	0	1	3	7

4.5. *Disaggregating estimates at sub-national levels*

There is of course an interest in obtaining information on the differences that may exist in the prevalence of undernourishment among individuals living in different areas within a country or belonging to different socioeconomic groups.

For global assessment purposes, FAO has been estimating food deprivation for each country as a whole only as described in the previous section. However, for assisting countries, the FAO methodology has been applied to derive sub-national estimates of the prevalence of undernourishment, given that the mean and CV of the distribution of dietary energy consumption as well as the minimum dietary energy requirement are estimated at representative sub-national levels from available HBS data of specific countries.

The data from HBS allow to measure the urban and rural dietary energy consumption, minimum dietary energy requirements and CV of dietary energy consumption due to income, CV(x|v). These estimations are illustrated below through a hypothetical example.

Consumption statistics:	***Urban***	***Rural***
Dietary energy consumption (kcals/person/day)	2380	2440
Minimum energy requirement (kcals/person/day)	1690	1650
Coefficient of variation of dietary energy consumption due to income **CV(x/r)** (%)	25	20
Coefficient of variation of dietary energy consumption **CV(x)** (%)	32.0	28.3
Food deprivation (%): Percentage of population with dietary energy consumption below the minimum energy requirement (indicator 1.9, target 1.C and goal 1 of the Millennium Development Goals)	17.4	10.2

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Annex :

Computation of Minimum Dietary Energy Requirements

A Hypothetical Country

The Minimum Dietary Energy Requirement can be derived applying the algorithm described below using data on country attained-height and population structure for different age groups by sex. The algorithm is implemented using exogenous information on weight for attained-height based on the Body Mass Index (BMI) in the reference population for children less than five years of age (WHO 2006), for children and adolescents from five to less than 18 years of age (WHO 2007) and for adults (WHO 1995) as well as dietary energy requirements for weight (for attained-height) and for weight-gain by age groups (FAO/WHO/UNU 2004). Additional dietary energy allowance for pregnancy is estimated using country birth rate.

The reference weight for country attained-height correspond to the 50th percentile (median) for age-groups of individuals less than 10 years while the 5th percentile for age-groups of individuals of 10 years and above. The MDER is a weighted average of MDERs for the various age groups and sex using the sex and age population structure provided by the UN Population Division (UN 2007).

Algorithm for estimating the Minimum Dietary Energy Requirement (MDER)			
Age-groups (years)/sex	**Total Energy Expenditure (TEE) equations**		
less than 1	linear TEE equation		
	country with high children undernutrition and infection (U5MR proxy high)		
Male / Female	**(-99.4 + 88.6*KG) +2* WG * ERwg**	**if U5MR > 10 ‰**	(U5MR=Under 5 mortality rate)
	country with low children undernutrition and infection (U5MR low)		
	(-99.4 + 88.6*KG) + WG * ERwg	**if U5MR <= 10 ‰**	
	where: KG=BMI*(height/100)^2 WG weight gain for age Erwg ER per kg of weight gain	50th percentile	
1 — 1.9	2nd degree TEE equation		
	country with high children undernutrition and infection (U5MR proxy high)		
Male	**0.93 * (310.2 + 63.3*KG - 0.263*KG^2) + 2 * WG * ERwg**		**if U5MR > 10 ‰**
Female	**0.93 * (263.4 + 65.3*KG - 0.454*KG^2) + 2 * WG * ERwg**		**if U5MR > 10 ‰**
	country with low children undernutrition and infection (U5MR proxy low)		
Male	**0.93 * (310.2 + 63.3*KG - 0.263*KG^2) + WG * ERwg**		**if U5MR <= 10 ‰**
Female	**0.93 * (263.4 + 65.3*KG - 0.454*KG^2) + WG * ERwg**		**if U5MR <= 10 ‰**
	(7% less to TEE for 2nd year)		
	where: KG=BMI*(height/100)^2 WG weight gain for age Erwg ER per kg of weight gain	50th percentile	
2 — 9.9	2nd degree TEE equation		
Male	**(310.2 + 63.3*KG - 0.263*KG^2) + WG * ERwg**		
Female	**(263.4 + 65.3*KG - 0.454*KG^2) + WG * ERwg**		
	where: KG=BMI*(height/100)^2 WG weight gain for age Erwg ER per kg of weight gain	50th percentile	
10-17.9	2nd degree TEE equation		
Male	**0.85 * (310.2 + 63.3KG - 0.263KG^2) + WG * ERwg**		
Female	**0.85 * (263.4 + 65.3KG - 0.454KG^2) + WG * ERwg**		
	KG=BMI$(HEIGHT/100)^2$	BMI 5th percentile	
	0.85 reflects PAL for sedentary physical activity (see blue book)		
18 - 29.9	PAL & Schofield TEE equation		
Male	**PAL * (692.2 + 15.057KG)**		
Female	**PAL * (486.6 + 14.818KG)**		
	KG=BMI$(HEIGHT/100)^2$	BMI 5th percentile	
	PAL=1.55 for sedentary physical activity (see blue book)		
30 - 59.9	PAL & Schofield TEE equation		
Male	**PAL * (873.1 + 11.472KG)**		
Female	**PAL * (845.6 + 8.126KG)**		
	KG=BMI$(HEIGHT/100)^2$	BMI 5th percentile	
	PAL=1.55 for sedentary physical activity (see blue book)		
60 - above	PAL & Schofield TEE equation		
Male	**PAL * (587.7 + 11.711KG)**		
Female	**PAL * (658.5 + 9.082KG)**		
	KG=BMI$(HEIGHT/100)^2$	BMI 5th percentile	
	PAL=1.55 for sedentary physical activity (see blue book)		
Pregnancy allowance = 210 kcal/day			

The inputs for implementing the algorithm are given for the hypothetical country in the table below. The sex and age group population structure (Pop. ratio) adds up to unit for weighting the population MDER estimate. The attained-heights are estimated using anthropometric data collected in nutritional surveys.

Input data from reference tables and country statistics											
Age group	Pop. ratio		Attained HEIGHT (H) (cm)		BMI		Weight gain for age (WG) (kg)		Energy per KG of weight gain (Er_kg) (kcal)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
less than 1	0.0174	0.0168	66.5	61.5	**17.30**	**16.90**	16.16	15.07	4.1	4.4
1 to 1.9	0.0172	0.0166	73.5	71.5	**16.10**	**15.70**	6.58	6.58	2	2
2 to 2.9	0.0169	0.0164	81.5	79.5	**15.80**	**15.50**	6.30	6.30	2	2
3 to 3.9	0.0166	0.0161	87.5	85.5	**15.40**	**15.30**	5.75	5.21	2	2
4 to 4.9	0.0162	0.0158	96.5	95.5	**15.30**	**15.30**	5.48	4.66	2	2
5 to 5.9	0.0158	0.0154	102.5	100.5	**15.26**	**15.25**	5.48	4.93	2	2
6 to 6.9	0.0154	0.0150	108.5	108.5	**15.38**	**15.32**	6.03	6.30	2	2
7 to 7.9	0.0150	0.0146	113.5	113.5	**15.60**	**15.52**	6.58	8.22	2	2
8 to 8.9	0.0145	0.0142	118.5	117.5	**15.89**	**15.87**	7.67	10.14	2	2
9 to 9.9	0.0140	0.0138	122.5	122.5	**16.23**	**16.34**	9.04	10.96	2	2
10 to 10.9	0.0136	0.0134	128.8	129	14.29	14.13	6.30	7.95	2	2
11 to 11.9	0.0131	0.0129	133.5	135.7	14.67	14.62	8.22	8.77	2	2
12 to 12.9	0.0127	0.0125	138.6	142.4	15.14	15.19	10.41	9.86	2	2
13 to 13.9	0.0123	0.0123	144.3	146.8	15.69	15.77	13.15	9.86	2	2
14 to 14.9	0.0121	0.0121	150.9	149.1	16.27	16.28	14.25	8.77	2	2
15 to 15.9	0.0119	0.0118	157.6	151	16.82	16.67	13.42	6.58	2	2
16 to 16.9	0.0116	0.0116	162.8	152.9	17.32	16.94	10.68	3.84	2	2
17 to 17.9	0.0113	0.0113	165	153.8	17.75	17.10	6.58	1.64	2	2
18 to 18.9	0.0108	0.0110	166	154.4	18.10	17.19				
19 to 19.9	0.0103	0.0106	166	154.4	17.80	16.87				
20 to 24.9	0.0437	0.0471	166	154.4	18.66	17.38				
25 to 29.9	0.0335	0.0380	166	154.4	18.66	17.38				
30 to 34.9	0.0260	0.0303	166	154.4	18.66	17.38				
35 to 39.9	0.0213	0.0245	166	154.4	18.66	17.38				
40 to 44.9	0.0180	0.0201	166	154.4	18.66	17.38				
45 to 49.9	0.0165	0.0177	166	154.4	18.66	17.38				
50 to 54.9	0.0142	0.0151	166	154.4	18.66	17.38				
55 to 59.9	0.0110	0.0113	166	154.4	18.66	17.38				
60 to 64.9	0.0093	0.0095	166	154.4	18.66	17.38				
65 to 69.9	0.0077	0.0082	166	154.4	18.66	17.38				
70+	0.0115	0.0129	166	154.4	18.66	17.38				

The BMI values, 5th and 50th percentiles, are from WHO references (1995, 2006 and 2007). The weight gains and energy requirements for weight gains are from the FAO/WHO/UNU Joint Report of the Expert Consultation on Human Energy Requirements (2004).

The computation of the MDER for a hypothetical country is illustrated below. The first table refers to males contributing 892 kilo-calories and the second table refers to females contributing 781 kilo-calories; the pregnancy allowance is of 7 kilocalories. The MDER for the population of the hypothetical country is 1680 kilo-calories per person per day.

Estimating the Minimum Dietary Energy Requirement (MDER) in a hypothetical country: MALES

	Attained HEIGHT (H) (cm)	BMI	Weight (KG) for attained height BMI*(height/100)^2 (kg)	Weight gain (WG) for age (Ref. Tb) (kg)		Energy per KG of weight gain (kcal)	PAL (Physical Activity Level)	Lower Limit of Energy Requirement (LLER) (kcal/caput/day)		Pop. ratio (p_{ij})	Total requirement per age group 2000 (kcal/day)	
less than 1	66.5	17.30	7.7	16.16		4.1		711	(-99.4+88.6*KG)+2*WG*Er_kg	0.017	12.39	
1 to 1.9	73.5	16.10	8.7	6.58		2		808	0.93*(310.2+63.3*KG-0.263*KG^2)+2*WG*Er_kg	0.017	13.90	
2 to 2.9	81.5	15.80	10.5	6.30		2		958		0.017	16.21	
3 to 3.9	87.5	15.40	11.8	5.75		2		1031		0.017	17.11	
4 to 4.9	96.5	15.30	14.2	5.48		2		1170		0.016	18.97	
5 to 5.9	102.5	15.26	16.0	5.48	(BMI_50th*((H_{ij}/100)^2))	2		1269		0.016	20.07	
6 to 6.9	108.5	15.38	18.1	6.03		2		1382	(310.2+63.3*KG-0.263*KG^2)+WG*Er_kg	0.015	21.28	
7 to 7.9	113.5	15.60	20.1	6.58		2		1489		0.015	22.27	
8 to 8.9	118.5	15.89	22.3	7.67		2		1607		0.015	23.30	
9 to 9.9	122.5	16.23	24.4	9.04		2		1714		0.014	24.08	
10 to 10.9	128.8	14.29	23.7	6.30		2		1426		0.014	19.36	
11 to 11.9	133.5	14.67	26.1	8.22		2		1534		0.013	20.06	
12 to 12.9	138.6	15.14	29.1	10.41		2		1660		0.013	21.01	
13 to 13.9	144.3	15.69	32.7	13.15		2		1809		0.012	22.33	
14 to 14.9	150.9	16.27	37.0	14.25		2		1978	0.85*(310.2+63.3*KG-0.263*KG^2)+WG*Er_kg	0.012	23.95	
15 to 15.9	157.6	16.82	41.8	13.42		2		2148		0.012	25.46	LLER*P_{ij}
16 to 16.9	162.8	17.32	45.9	10.68		2		2284		0.012	26.52	
17 to 17.9	165	17.75	48.3	6.58		2		2355		0.011	26.57	
18 to 18.9	166	18.10	49.9				1.55	2237		0.011	24.20	
19 to 19.9	166	17.80	49.0				1.55	2218	1.55*(692.2+15.057*KG)	0.010	22.77	
20 to 24.9	166	18.66	51.4		(BMI_5th*((H_{ij}/100)^2))		1.55	2273		0.044	99.39	
25 to 29.9	166	18.66	51.4				1.55	2273		0.033	76.11	
30 to 34.9	166	18.66	51.4				1.55	2268		0.026	58.97	
35 to 39.9	166	18.66	51.4				1.55	2268		0.021	48.27	
40 to 44.9	166	18.66	51.4				1.55	2268	1.55*(873.1+11.472*KG)	0.018	40.79	
45 to 49.9	166	18.66	51.4				1.55	2268		0.016	37.36	
50 to 54.9	166	18.66	51.4				1.55	2268		0.014	32.11	
55 to 59.9	166	18.66	51.4				1.55	2268		0.011	24.84	
60 to 64.9	166	18.66	51.4				1.55	1844		0.009	17.08	
65 to 69.9	166	18.66	51.4				1.55	1844	1.55*(587.7+11.711*KG)	0.008	14.13	
70+	166	18.66	51.4				1.55	1844		0.011	21.19	
Total											892.05	

Estimating the Minimum Dietary Energy Requirement (MDER) in a hypothetical country: FEMALES

	Attained HEIGHT (H) (cm)	BMI	Weight (KG) for attained height BMI*(height/ 100)^2 (kg)	Weight gain (WG) for age (Ref. Tb) (kg)		Energy per KG of weight gain (kcal)	PAL (Physical Activity Level)	Lower Limit of Energy Requirement (LLER) (kcal/caput/day)		Pop. ratio (p_{ij})	Total requirement per age group 2000 (kcal/day)	
less than 1	61.5	16.90	6.4	15.07		4.4		600	(-99.4+88.6*KG)+2*WG*Er_kg	0.017	10.07	
1 to 1.9	71.5	15.70	8.0	6.58		2		732	0.93*(263.4+65.3*KG-0.454*KG^2)+2*WG*Er_kg	0.017	12.15	
2 to 2.9	79.5	15.50	9.8	6.30		2		872		0.016	14.28	
3 to 3.9	85.5	15.30	11.2	5.21		2		947		0.016	15.24	
4 to 4.9	95.5	15.30	14.0	4.66	(BMI_50th*((H_{ij}/100)^2))	2		1096		0.016	17.27	
5 to 5.9	100.5	15.25	15.4	4.93		2		1171		0.015	18.04	
6 to 6.9	108.5	15.32	18.0	6.30		2		1306	(263.4+65.3*KG-0.454*KG^2)+WG*Er_kg	0.015	19.62	
7 to 7.9	113.5	15.52	20.0	8.22		2		1404		0.015	20.54	
8 to 8.9	117.5	15.87	21.9	10.14		2		1497		0.014	21.28	
9 to 9.9	122.5	16.34	24.5	10.96		2		1614		0.014	22.27	
10 to 10.9	129	14.13	23.5	7.95		2		1331		0.013	17.81	
11 to 11.9	135.7	14.62	26.9	8.77		2		1456		0.013	18.83	
12 to 12.9	142.4	15.19	30.8	9.86		2		1587		0.013	19.92	
13 to 13.9	146.8	15.77	34.0	9.86		2		1684		0.012	20.66	
14 to 14.9	149.1	16.28	36.2	8.77		2		1745	0.85*(263.4+65.3*KG-0.454*KG2)+WG*Er_kg	0.012	21.03	
15 to 15.9	151	16.67	38.0	6.58		2		1789		0.012	21.16	LLER*P_{ij}
16 to 16.9	152.9	16.94	39.6	3.84		2		1825		0.012	21.17	
17 to 17.9	153.8	17.10	40.4	1.64		2		1841		0.011	20.86	
18 to 18.9	154.4	17.19	41.0				1.55	1695		0.011	18.62	
19 to 19.9	154.4	16.87	40.2				1.55	1678	1.55*(486.6+8.126*KG)	0.011	17.74	
20 to 24.9	154.4	17.38	41.4		(BMI_5th*((H_{ij}/100)^2))		1.55	1706		0.047	80.27	
25 to 29.9	154.4	17.38	41.4				1.55	1706		0.038	64.76	
30 to 34.9	154.4	17.38	41.4				1.55	1833		0.030	55.52	
35 to 39.9	154.4	17.38	41.4				1.55	1833		0.025	44.91	
40 to 44.9	154.4	17.38	41.4				1.55	1833	1.55*(845.6+8.118*KG)	0.020	36.74	
45 to 49.9	154.4	17.38	41.4				1.55	1833		0.018	32.50	
50 to 54.9	154.4	17.38	41.4				1.55	1833		0.015	27.60	
55 to 59.9	154.4	17.38	41.4				1.55	1833		0.011	20.74	
60 to 64.9	154.4	17.38	41.4				1.55	1604		0.010	15.29	
65 to 69.9	154.4	17.38	41.4				1.55	1604	1.55*(658.5+9.082*KG)	0.008	13.15	
70+	154.4	17.38	41.4				1.55	1604		0.013	20.73	
Total											780.79	