AIP RESEARCH REPORT
NM$9 (01-25)

Net merit as a measure of lifetime profit: 2025 revision

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Overview

The lifetime net merit (NM$) index ranks dairy animals based on their combined genetic merit for economically important traits (Cole et al., 2021). Indexes are updated periodically, such as at genetic base changes, to reflect prices expected in the next few years. This update revises some methods to estimate trait values and many income and cost variables, such as milk prices, feed requirements, and reproductive options, but does not yet include genetic evaluations for potential new traits. Selection on an index is the best way to improve cows and profit in each generation.

The index combines economic values for 12 individual traits plus 5 composite subindexes. Calving ability $ (CA$) combines 4 service sire and maternal grandsire effects on calving ease and stillbirth, while health trait $ (HTH$) combines 6 disease resistance traits of cows. Conformation (type) traits are included via udder composite (UDC), feet/leg composite (FLC), and body weight composite (BWC). The CA$ and HTH$ subindexes are not published directly and are available only for some breeds. Feed Saved (FSAV) combines BWC with residual feed intake (RFI) that measures the difference of actual and expected feed intake. Relative economic values for BWC and RFI are presented separately because BWC is available for all breeds, whereas FSAV is available only for Holsteins.

The 2025 NM$ index gives more emphasis to butterfat and less emphasis to protein than in the 2021 index due to recent price trends. Cow livability (LIV) and heifer livability (HLIV) get more emphasis and productive life (PL) gets less emphasis due to higher cull cow and heifer calf prices. BWC gets more negative emphasis because of larger maintenance costs estimated from actual feed intake data, and RFI gets more emphasis due to the higher reliability (REL) and standard deviation of PTAs obtained from more feed intake records. The −11% emphasis on BWC and −6.8% emphasis on RFI combine for +17.8% emphasis on FSAV. Relative emphasis on fertility traits daughter pregnancy rate (DPR), cow conception rate (CCR), heifer conception rate (HCR), and early first calving (EFC) were affected by revised reproductive options.

The 2025 and 2021 NM$ indexes are correlated by 0.992 for young Holstein bulls and 0.981 for recently progeny-tested bulls.

A presentation on proposed Net Merit $ revisions for 2025 including graphs of lifetime incomes and expenses can be viewed here.

Updated economic values

New economic values for each unit of predicted transmitting ability (PTA) and relative economic emphasis of traits will be implemented in April 2025 for NM$, cheese merit (CM$), fluid merit (FM$), and grazing merit (GM$). Since 2021, relative emphasis is computed using the SD of PTA whereas relative value is computed using the SD of true transmitting ability (TTA). The SDs of TTA were mostly obtained from Interbull estimates of SD from August 2024. Relative value shows which traits are most important and each trait's potential contribution to NM$ progress, whereas relative emphasis shows how traits contribute to the current ranking given their limited data and prediction reliability (REL) (Zhang and Amer, 2021). This difference has no effect on the economic values or ranking and little effect on the reported emphasis because most traits have similar RELs, but the relative value of −14.2% for RFI was equivalent to only −6.8% relative emphasis because FSAV and RFI have lower REL than most other traits. The relative emphasis below was calculated using PTA SD for young Holstein bulls born in 2024; progeny-tested bulls and older cows have differing REL and emphasis due to effects of selection, generation intervals, and phenotypes available for the selected traits.

The traits and composites are displayed in the historical order that they were included in NM$:

Trait	Units	SD	Value ($/PTA unit)				Relative emphasis (%)			
			NM$	FM$	CM$	GM$	NM$	FM$	CM$	GM$
Milk	Pounds	566.88	0.022	0.122	-0.02	0.022	3.2	17.6	-2.7	3
Fat	Pounds	24.88	5.01	5.01	5.01	5.11	31.8	31.7	30	30.3
Protein	Pounds	15.27	3.33	0	4.73	3.39	13	0	17.4	12.3
PL	Months	1.70	30	30	30	17	13	13	12.3	6.9
SCS[1]	Log	0.14	-74	-42	-95	-75	-2.6	-1.5	-3.2	-2.5
BWC	Composite	0.76	-57	-57	-57	-72	-11	-11	-10.4	-13
UDC	Composite	0.65	8	8	8	10	1.3	1.3	1.3	1.5
FLC	Composite	0.53	3	3	3	3	0.4	0.4	0.4	0.4
DPR	Percent	1.37	6	6	6	17.3	2.1	2.1	2	5.6
CA$	Dollars	13.1	1	1	1	1.1	3.3	3.3	3.2	3.4
HCR	Percent	1.27	1.5	1.5	1.5	3	0.5	0.5	0.5	0.9
CCR	Percent	1.63	4.3	4.3	4.3	13.3	1.8	1.8	1.7	5.2
LIV	Percent	1.62	14.3	14.3	14.3	11.4	5.9	5.9	5.6	4.4
HTH$	Dollars	5.9	1	1	1	1.1	1.5	1.5	1.4	1.5
RFI	Pounds	76	-0.35	-0.35	-0.35	-0.42	-6.8	-6.8	-6.4	-7.6
EFC	Days	2.05	2	2	2	1.7	1	1	1	0.8
HLIV	Percent	0.36	8.2	8.2	8.2	6.6	0.8	0.7	0.7	0.6

[1] SCS = somatic cell score

The SDs of TTAs for NM$, CM$, and FM$ are all estimated to be $228, about the same as the $234 for 2021 indexes, because higher feed costs offset the higher milk prices. The SDs for GM$ would be larger because of longer PL in grazing herds, except that milk yield differences are often reduced in such herds. Economic values in GM$ are rescaled to make the SDs equal to the other indexes.

An economic value is the added profit caused when a given trait changes by 1 unit and all other traits in the index remain constant. For example, an economic value for protein is determined by holding pounds of milk and fat constant and examining the increase in price when milk contains an extra pound of protein. The genetic merit for each trait of economic value ideally should be predicted from both direct and indirect measures. Multiple-trait methods are currently used in the conformation, fertility, and PL with LIV trait groups. The economic value of a trait may change when other correlated traits are added to the index. Selection of animals to be parents of the next generation is most accurate when all traits of economic value are included in the index. Selection for some traits measuring efficiency, longevity, or disease resistance may have additional benefits to consumers but only the direct benefits for herd profit are considered in the economic math.

Relative values for each trait expressed as a percentage of total selection emphasis are obtained by multiplying the economic value by the SD for TTA and then dividing each individual value by the sum of the absolute values. The SDs differ slightly among breeds and are set to 0 for traits not evaluated for individual breeds. Economic values are derived using trait averages for Holsteins, and missing traits such as RFI are assumed to be 0 for other breeds. That increases relative values of other traits for those breeds because relative values sum to 100%. Relative economic values for NM$ traits within each breed using the subset of traits and genetic SDs specific to the breed's evaluation, are presented below:

Trait	Ayrshire	Brown Swiss	Guernsey	Holstein	Jersey	Milking Shorthorn
Milk	3.7	3.3	3.6	2.9	3.4	3.7
Fat	30.2	26.9	28.2	24.7	29.9	30.2
Protein	15.2	14.3	14.4	11.4	15.2	15.2
PL	16.9	18	17.5	12.3	15.8	16.9
SCS	-3.6	-3.3	-3.3	-2.6	-2.6	-3.6
BWC	-14.4	-13	-15.3	-11.2	-13	-14.4
UDC	2	1.3	1.1	1.2	1	2
FLC	0.6	0.5	0.6	0.5	0.5	0.6
DPR	3.5	3.4	3.4	2.6	3.6	3.5
CA$	0	2	0	3.3	0	0
HCR	0.9	0.9	0.8	0.7	0.9	0.9
CCR	2.7	2.8	3	2.3	2.8	2.7
LIV	5.1	6.6	7.6	5.9	6	5.1
HTH$	0	2.5	0	2	2.5	0
RFI	0	0	0	-14.2	0	0
EFC	1.2	1.2	1.1	1	1.3	1.2
HLIV	0	0	0	1.2	1.5	0

NM$ calculation

Calculation of NM$ and its REL can be demonstrated using the following example Holstein:

Trait	Example PTA	Example REL (%)
Milk	+2,073	96
Fat	+114	96
Protein	+70	96
PL	+5.1	83
SCS	2.90 (−3.00)	90
BWC	−1.49	95
UDC	+0.76	95
FLC	+0.58	93
DPR	−0.1	79
CA$	+27	93
HCR	+0.7	82
CCR	+1.4	78
LIV	+0.9	74
HTH$	+11	61
RFI	+21	20
EFC	+4.4	72
HLIV	+1.1	55

The PTAs for each trait are multiplied by the corresponding economic value and then summed. For Holsteins, the BWC and RFI are already combined into FSAV using the math and economic value in the feed saved section. For the example bull, FSAV is 205 with 47% REL. A value of 3 must be subtracted from PTA for SCS, which originally was the phenotypic mean of SCS and is still used as the base for all breeds. After that subtraction and combining all traits, the NM$ for this example bull is $1,171, FM$ is $1,143, CM$ is $1,185, and GM$ is $1,168, with REL of NM$ = 84%.

Calculation of NM$ also can be expressed in matrix form:

$$\mathbf{NM\$} = \mathbf{a}'\mathbf{u},$$

where vector **a** contains each trait's economic value and vector **u** contains each trait's PTA. The average of 3.00 for SCS is removed from the corresponding element of **u**.

The REL of NM$ is computed using matrix algebra from REL of each trait and genetic correlations among the traits. The NM$ REL is the variance of predicted NM$ divided by the variance of true NM$:

$$\mathbf{REL\ NM\$} = \mathbf{r}'\mathbf{Gr}/\mathbf{v}'\mathbf{Gv},$$

where **r** contains the relative economic values multiplied by the square root of REL for each PTA trait, **G** contains the genetic correlations among the traits, and **v** contains the relative economic values for the traits. For the example bull, REL is 85%. This is less than the 91% REL reported with the 2018 NM$ formula because FSAV has high value but lower REL than previously selected traits.

Trait parameters

Genetic correlations among all traits and composites were estimated from correlations among PTAs of Holstein bulls with high REL because restricted maximum-likelihood estimates were not available between all traits. Genetic and phenotypic correlations for each of 24 PTA traits and composites are provided in supplemental table https://www.ars.usda.gov/arsuserfiles/80420530/publications/arr/NMcorrelations2025.txt

for Holsteins along with SDs of TTAs and heritabilities for each breed.

Expected genetic progress

Correlations of PTAs for each trait with NM$, FM$, CM$, and GM$ were obtained from young Holstein females born in 2023. The expected PTA progress was obtained as the correlation of PTA with NM$ multiplied by the PTA SD multiplied by 0.35, which is the expected annual trend in SD of NM$. The PTA SDs generally are lower than the TTA SDs because of selection and because RELs are less than 1. Genetic trend (change in breeding value) equals twice the expected progress for PTA. Thus, multiplication of annual PTA gain by 20 gives expected genetic progress per decade.

Expected correlations of each trait with the 4 indexes and progress in actual units expected from selection on NM$ are:

PTA trait[1]	NM$	FM$	CM$	GM$	NM$ PTA change/year	NM$ breeding value change/decade
Milk	0.387	0.484	0.346	0.289	76.856	1,537.127
Fat	0.784	0.747	0.791	0.61	6.827	136.548
Protein	0.668	0.667	0.662	0.512	3.569	71.37
PL	0.65	0.635	0.652	0.51	0.387	7.734
SCS	-0.253	-0.22	-0.268	-0.183	-0.012	-0.248
BWC	-0.432	-0.464	-0.414	-0.369	-0.115	-2.297
UDC	0.086	0.077	0.089	0.058	0.019	0.389
FLC	-0.09	-0.11	-0.081	-0.077	-0.017	-0.333
DPR	-0.021	-0.05	-0.008	0.04	-0.01	-0.198
CA$	0.459	0.449	0.459	0.376	2.104	42.073
HCR	0.262	0.263	0.259	0.242	0.116	2.327
CCR	0.19	0.165	0.198	0.208	0.108	2.163
LIV	0.348	0.326	0.354	0.274	0.197	3.942
GL	-0.191	-0.189	-0.19	-0.151	-0.074	-1.47
HTH$	0.438	0.402	0.451	0.338	0.905	18.106
RFI	-0.183	-0.192	-0.178	-0.163	-4.862	-97.247
MFEV	0.124	0.117	0.125	0.091	0.004	0.078
DA	0.327	0.318	0.328	0.248	0.034	0.686

KETO	0.244	0.213	0.254	0.183	0.049	0.972
MAST	0.225	0.181	0.243	0.166	0.094	1.889
MET	0.44	0.421	0.444	0.353	0.085	1.695
RETP	0.05	0.043	0.053	0.041	0.004	0.084
EFC	0.412	0.42	0.405	0.337	0.295	5.909
HLIV	0.141	0.153	0.136	0.1	0.018	0.355

Derivation of economic values

Prices, math, and assumptions used in deriving economic values are shown below for FSAV, HLIV, EFC, health traits, fertility traits, yield traits, SCS, PL and LIV, and type traits. Economic values for most traits in CM$, FM$, and GM$ are the same as in NM$. Primary differences in economic values for grazing versus confinement herds are 2.5 times higher value of fertility to maintain seasonal calving, 15% less production per lactation but 50% more lactations, 25% less death loss, and 25% less MAST incidence (Gay et al, 2014).

Feed saved

Since 1994, NM$ has subtracted the expected feed costs associated with milk, fat, and protein yields and, since 2000, expected feed costs associated with BWC have also been subtracted. Since 2021, actual feed intake data, instead of only expected feed intake based on correlated traits, is also used to estimate feed costs. The subtraction to calculate net instead of gross income was the main reason for the word “net” in NM$. The FSAV evaluation includes the economic value of cow body weight composite (BWC) along with actual feed intake records within >11,000 lactations of >8,000 Holstein cows in U.S. and Canadian research herds. Most research cows have high genetic merit, production, and diets comparable to cows in successful commercial farms in the same regions.

Evaluations for RFI (the difference between actual and expected intake) are expressed in pounds of dry matter intake (DMI) per lactation and computed with methods described in Li et al., 2020. Cost reductions due to less actual than expected intake and those associated with lower BWC are combined for Holsteins into FSAV with positive values favorable. The PTA and REL for FSAV are calculated for April 2025 as:

$$\text{PTA FSAV} = -1(\text{PTA RFI}) - 162.7(\text{PTA BWC});$$
$$\text{REL FSAV} = 0.617(\text{REL RFI}) + 0.383(\text{REL BWC}).$$

The PTAs for BWC contribute more than RFI to FSAV because they have higher REL, and correlations with FSAV are −0.85 for BWC and −0.52 for RFI. For other breeds, NM$ continues to include the costs for BWC but not RFI or FSAV until feed data become available for those breeds.

Maintenance

Large cows and bulls were favored by dairy cattle breeders for many years, but many research studies concluded that cow size should have negative value in an index because milk income already was accounted for, but feed costs were not. Feed costs are the largest cost of producing milk and are now assumed to average 39% of the value of extra production plus 19% for cow maintenance for a total of 58% of the income from milk produced. Both percentages are larger than assumed previously. Higher producing cows use a smaller percentage of feed for maintenance and thus are often more profitable.

Incomes and expenses assigned to BWC, as defined in the type traits section, include the cost of extra feed eaten by heavier cows for body maintenance, marginal cost of growing larger replacements ($0.85/pound), growth cost from replacement to mature weight ($0.56/pound), extra beef income from heavier cull cows ($0.90/pound), income from heavier calf weights (0.06 pounds/pound of cow weight), and increased housing costs for larger cows ($0.04/pound of cow weight/lactation). Maintenance is the main cost because cull cow income offsets much of the heifer growth cost. Beef cattle prices are high and seem to have a steep 5-year cycle recently.

Maintenance costs were estimated from 8,513 lactations of 6,621 research cows by regressing DMI kg/day on the cow’s own phenotypic metabolic BW (MBW) or the cow’s or her sire’s genomic BWC. Phenotypic regression on MBW gave 0.108 kg DMI/kg $BW^{0.75}$/day, cow’s genomic regression on BWC gave 0.275 kg DMI/day, and sire genomic regression on BWC gave 0.126 kg DMI/day, which was about half the regression on cow estimated breeding value as expected. The phenotypic regression was multiplied by 365 and divided by 6.67 to convert daily to annual intake and MBW to BW. The genomic regressions were multiplied by 365 and divided by 17.28 to convert BWC to BW; the sire genomic regression was further multiplied by 2, giving estimates of 5.8 and 5.3 pounds DMI/lactation, which agree with the estimate of 5.9 from regression on cow’s phenotypic BW. A final estimate of 5.5 pounds DMI/lactation is used in NM$.

Estimates of lactation maintenance and their standard errors based on data from the Council on Dairy Cattle Breeding (Bowie, MD) are summarized:

Estimate	Maintenance per year (pounds DMI/pound BW)	Standard error
Phenotypic regression	5.9	±0.14
Genomic regression	5.8	±0.31
Sire genomic regression	5.3	±0.55
NM$ new value	5.5	…

The 5.5 pounds DMI/lactation multiplied by 35 pounds BW/unit of BWC convert to 162.7 pounds DMI/1 point BWC. The other lifetime incomes and expenses convert to −2.7 pounds DMI/1 point BWC for a net of 160. The economic value in NM$ is then $160 \times (2.70\ lactation) \times (\$0.13/pound\ DMI) = -\$57$. The direct selection emphasis in NM$ is now 11.1% against BWC, which is included in FSAV for Holsteins.

Feed cost for yield components

Feed intakes associated with each milk component were also examined from the U.S. research herd data (Toghiani et al., 2024). Several methods to estimate feed costs for milk components each gave differing costs, especially for fat yield. The genomic regressions used 305-day yields in pounds to predict daily DMI kg and were multiplied by 305 and 2.2 to match the units. The sire genomic regressions were further multiplied by 2 because sires contributed only half the genes. The marginal feed costs used a DMI price $0.13/pound whereas the NM$ 2021 cost was calculated with $0.11. Feed costs used in the Dairy Margin Coverage program averaged about $10/cwt in 2019-2021 but increased to $13/cwt in 2022-2024.

The feed required for milk, fat, and protein from phenotypic and genetic regressions and the total dollar value of feed eaten to produce an additional 100 pounds of standardized milk with 3.5% fat and 3.0% protein are compared below:

Method	Marginal feed cost ($)/ 100 pounds standardized milk	DMI (pounds) required per unit of component output					
		Milk	Milk standard error	Fat	Fat standard error	Protein	Protein standard error
Phenotypic regression	3.45	0.014	±0.006	3.06	±0.01	4.79	±0.25
Genomic regression	8.98	0.080	±0.03	11.30	±0.47	9.35	±0.87
Sire genomic regression × 2	6.06	0.048	±0.04	6.73	±0.94	4.98	±1.75
NM$ 2021	5.23	0.120	…	5.00	…	6.00	…
NM$ 2025	7.48	0.100	…	8.00	…	6.50	…
Theoretical (Dado et al. 1994)	6.65	0.112	…	4.42	…	8.17	…
ECM[1] (National Research Council, 2001)	4.89	0.122	…	4.82	…	2.85	…

[1] Energy-corrected milk

Phenotypically, more feed was needed to produce protein than to produce fat. Total feed cost from the phenotypic regressions were only $3.45/100 pounds of standardized milk, which seems too low compared with a milk income of $19.00. The low estimate from phenotypic regression of DMI on the cow's own fat yield was probably because the model accounted for change in the cow's BW but not in her body composition during the feeding trial.

Genetically, using the cow's genomic evaluations to predict the cow's phenotypic feed intake gave the opposite result, with more feed required to produce fat than to produce protein and a much higher total feed cost. Those regression coefficients agreed with the fat to protein ratio assumed in ECM, but with much less feed intake estimated for milk (lactose) than in ECM.

Nearly all other countries assumed that feed costs for each component were proportional to ECM (Peter Amer, Abacusbio, New Zealand, personal communication, 2020), but more detailed estimates and estimation methods are now available. Small standard errors indicate that the phenotypic and genomic regressions really differ, and biological explanations are needed. Although RFI can be defined as independent of yield and body weight using either phenotypic or genetic regressions, genetic regressions should be used for combining genetic evaluations (Tempelman and Lu, 2020).

If needed, a PTA for total DMI/lactation can be predicted as $0.10 \times (PTA\ milk) + 8 \times (PTA\ fat) + 6.5 \times (PTA\ protein) - FSAV$ to combine the feed intakes associated with yield, BWC, and RFI. Expression of FSAV as pounds instead of dollars makes the PTAs more stable regardless of prices and more similar to yield traits expressed as pounds per lactation. The feed costs associated with milk, fat, and protein are not included in FSAV but are directly subtracted from yield trait economic values to obtain net income as in all previous NM$ formulas.

Heifer livability

Genomic evaluations for HLIV were developed by Neupane et al. (2021) and implemented in December 2020. The HLIV PTAs are expressed in percentage points of additional calves that live, and positive PTAs are favorable. Increasing heifer survival can have great economic benefits because rearing of replacement heifers is a major cost on dairy farms. Mortality also affects selection intensity of the herd, which will ultimately reduce genetic gain.

Heifer calves were assumed to be worth an average of $500 across the ages when calf death losses occur. Most deaths occur in the early months but raising expenses are also higher in the early months. Current assumptions are a $400 value for newborn heifers and a $1,794 value at freshening with an average cost of heifer loss estimated to be $820, which gives HLIV a value of $8.20 per 1%. Additional value could be justified for correlated calf health costs, for the livability of bull calves, or for heifers that die after the 18-month edit limit, but direct data were not available for those costs.

Early first calving

Genomic evaluations for EFC were developed by Hutchison et al. (2017) and implemented in 2019 (Council on Dairy Cattle Breeding, 2019). The trait EFC is measured in days with positive PTAs indicating earlier calving and has an SD of 2.5 days. An edit now excludes records initiated by abortion so that heifers that calve early only get credit if the lactation is normal and usable. The primary benefit of EFC is to reduce the time required to raise replacements with costs valued at $75/month or $2.50/day. Milk production records are standardized for age at calving, but the actual 305-day yield produced in first lactation is reduced by about 5 pounds per day of EFC. This lost milk yield is valued at $0.17/pound but with a reduced feed cost of $0.08/pound, which gives a net economic value of $\$2.50 - 5 \times (\$0.17 - \$0.08) = \$2.05/day$ for EFC.

Relative emphasis on EFC is 1.0% of NM$. With EFC included in the NM$ index, emphasis on HCR declined to 0.6% because HCR included an indirect benefit for EFC that is now replaced by the direct benefit of HCR. The two traits EFC and HCR have a moderate genetic correlation of 0.32 for Holsteins. Other benefits associated with EFC are longer PL and higher fertility and thus more lifetime milk yield but with additional stillbirths. Those benefits and costs are already accounted for in NM$.

Benefits and costs of EFC are nonlinear especially on the phenotypic scale and may not apply to breeding and calving at very young ages. Heifers are often bred at a given weight rather than age, and high PTAs for EFC indicate better fertility and heifer growth rate, a trait that is not yet measured directly. Adverse effects on stillbirth and calving difficulty can be managed through careful mate selection (Cole et al., 2007), but farmers and consumers may prefer management and selection strategies that improve EFC without increased stillbirths or calving difficulty.

Health traits

Six health traits recorded by producers are evaluated for Holsteins, Jerseys, and Brown Swiss: clinical mastitis (MAST), ketosis (KETO), retained placenta (REPL), metritis (METR), displaced abomasum (DA), and milk fever (MFEV; hypocalcemia). Cows with genes that keep them healthy are more profitable than cows with health conditions that require extra farm labor, veterinary treatment, and medicine.

Economic values were obtained as averages of two research studies plus additional yield losses not fully accounted for in published genetic evaluations for yield traits. Direct treatment, labor, and discarded milk costs for health disorders were estimated from veterinary and producer survey responses (Liang et al., 2017) and obtained health treatment costs from eight cooperating herds in Minnesota (Donnelly, 2017; Hazel et al., 2020). Some yield losses associated with health conditions are not fully accounted for when 305-day lactation records include adjusted test days that are coded as sick or abnormal. Economic values, relative values, and SDs of TTAs for the six health traits and LIV follow. Those costs were multiplied by 1.3 to account for nearly 30% inflation since the 2017 estimates and are shown below along with new estimates of genetic variance.

The HTH$ index sums the lifetime values obtained by multiplying the per case values by 2.70, the average number of lactations per lifetime, and then multiplying by 0.01 because the 6 health trait PTAs are expressed as percentages.

Trait (cases/lactation, %)	TTA SD	Value ($/case) = *(direct cost + yield adjustment) * inflation*	Value ($/lifetime)	Relative value (%)	
				HTH$	NM$
MFEV	0.4	44 =(38 − 4) * 1.3	1.19	2.0	0.03
DA	0.6	256 =(178 + 19) * 1.3	6.91	19.3	0.29
KETO	1.6	36 =(28 + 0) * 1.3	0.97	6.7	0.10
MAST	2.9	98 =(72 + 3) * 1.3	2.65	33.1	0.50
METR	1.6	146 =(105 + 7) * 1.3	3.94	28.0	0.42
RETP	1.0	88 =(64 + 4) * 1.3	2.38	10.9	0.16
HTH$	$8.50	…		100	1.5

Any yield losses not accounted for by yield PTAs were estimated by comparing healthy and unhealthy cows with and without the milk, fat, and protein abnormal test-day adjustments of Wiggans et al. (2003). Most health traits had only 2-pound differences for fat and 1-pound differences for protein between adjusted and unadjusted lactation yields. The value per lactation was $1.23 for fat and $1.32 for protein, resulting in only about $4 more value to add to direct health costs/case to account for unadjusted yield minus published adjusted yield. Only DA had bigger differences of 6 pounds for fat and 8.5 pounds for protein, but those differences added only $19 to the $178 value of direct costs assumed for DA. Because DA has acute effects requiring surgery, cows with DA may be more likely be coded as sick or detected as abnormal on test day. Relative values for each trait are obtained by multiplying economic value by TTA SD and then dividing each individual value by the sum of the absolute values.

Fertility traits

Measures of fertility in merit indexes are DPR and CCR for cows and HCR and EFC for heifers. Separating the benefits from CCR and DPR is not simple because the two traits overlap. Both are major components of PL, but the benefits from more lactations are already included in the PL economic value. Semen price ($15/unit) and insemination labor costs ($10/unit) are proportional to the number of services and are the main expense for CCR, whereas reduced profit from lactations longer or shorter than optimum, estimated to be $0.75/day open, are the main expense in DPR which measures the time needed to become pregnant. The economic loss for 1 day open is then converted to DPR by multiplying by −4. Numbers of services were assumed to average 1.8 for heifers and 2.38/lactation for cows, which is equivalent to conception rates of 56% and 42%, respectively. Synchronization costs were $13 per insemination and pregnancy checks were $5/exam (Lauber et al., 2021).

For heifers, losses from culling for poor fertility should be included in HCR because PL includes only cow losses. If heifers are culled after 5 unsuccessful services, $(1 - 0.56)^5 = 1.6\%$ of heifers would be culled, with 0.2% more for each 1% lower HCR. Alternatively, natural service might be used for problem breeders, but with potentially higher cost than for artificial insemination. When infertile heifers are culled at about 1,000 pounds live weight, economic loss equals the raising cost of $1,200 minus the beef value of $900 = $300. Total value of HCR including insemination costs, heat detection, pregnancy checks, and reproductive culling was $(\$15 + \$10 + \$13 + \$5) \times 1.8/100 + \$300 \times 0.002 = \$1.47$.

For cows, the value per lactation was $(\$15 + \$10 + \$13 + \$5) \times 2.38/100 = \$1.02$ for CCR and value for DPR was $(4 \times \$0.75) = \$3$. Per lactation costs for CCR and days open are converted to lifetime values by multiplying by 2.4, which assumes that cows have 2.7 lactations but that no inseminations are attempted for 30% of the cows during their final lactation because a decision to cull was made previously for other reasons (2.4 = 2.7 − 0.3). With synchronized breeding, voluntary waiting period may differ for individual cows, and some DPR differences may now be a function of management decisions rather than fertility. Thus, a small portion ($0.80) of the per-lactation cost of DPR was subtracted from DPR and added instead to CCR. Lifetime value of CCR was $(\$1.02 + \$0.80) \times (2.4) = \$4.30$. Numbers of calves born increase with both DPR and PL. At a constant PTA PL, 1% higher DPR results in about 0.3% more calves per lifetime with an average value of $400, which then results in an extra $1.20/PTA unit of DPR. Lifetime value of DPR was $(\$3 - \$0.80) \times (2.4) + \$1.20 = \$6$.

Yield traits

A base price of $19.00 was assumed for milk containing 3.5% fat, 3% true protein, and 350,000 somatic cells/ml before deducting hauling charges, which were assumed to be $0.50 based on actual costs in 2023 (about $0.01/100 pounds/loaded mile times 50 miles on average). The milk price after hauling charges was equal to $18.50. The Holstein base cows born in 2020 averaged 3.81% fat and 3.10% fat, for an effective price of $20.19 with premiums. Component prices follow, along with marginal feed costs required for higher yield with the non-yield traits in NM$ held constant; values in the volume column are computed as (milk value) − 3.5(fat value) − 3(protein value) divided by 100:

Index	Milk ($/100 pounds)	Fat ($/pound)	Protein ($/pound)	Volume ($/pound)
NM$ and GM$	18.50	2.90	2.08	0.0261
CM$	18.50	2.90	2.60	0.0105
FM$	18.50	2.90	0.85	0.0631
Marginal feed cost	7.49	1.04	0.85	0.0130

Feed costs for cows are assumed to average 58% of the milk price divided into 39% marginal costs for milk, fat, protein, and a separate 19% for maintenance cost using actual feed intake data from 8,513 lactations of 6,621 dairy cows in U.S. research herds (Toghiani et al., 2024). Those costs were presented in the feed saved section. Those DMI requirements in pounds were converted to DMI cost by multiplying by $0.13/pound and then by number of lactations for use in lifetime NM$. Along with the feed cost, costs of $0.002 were also subtracted for bulk tank, equipment, and electricity costs to cool and store each pound of milk. Cooling costs were cut in half on many farms by pre-cooling milk. The milk price did not include costs or benefits from participating in the USDA Margin Protection Program or other direct cash payments.

Correlations of merit indexes based on proven Holstein bulls were 0.996 for NM$ with CM$, 0.976 for NM$ with FM$, and 0.972 for NM$ with GM$. A small protein premium equal to feed cost plus health cost is included to make FM$ more acceptable as a breeding goal and results in no direct selection for or against protein in the FM$ index. Producers that expect low future protein premiums should select on FM$, and those that expect high protein premiums should select on CM$; breeders targeting the U.S. average price should select on NM$.

The value of milk, fat, and protein is converted from a lactation basis to a net lifetime basis by subtracting feed and hauling costs and then multiplying by the average number of record equivalents in a lifetime. For Holsteins, the average number of record equivalents is 2.70, and the lifetime value of PTA protein in NM$ is (2.08 − 0.85)x2.70 = $3.32.

Prices for milk, fat, and protein vary by use of milk and across time. Average prices for milk and individual components in Federal order markets are available from USDA's Agricultural Marketing Service. Actual prices from 2006 until May 2024 for class III milk used in cheese making are:

Year	Milk ($/100 pounds)	Fat ($/pound)	Protein ($/pound)	Volume ($/pound)	SCC ($/1,000 cells)[1]
2024	18.37	3.38	1.68	0.0150	-0.00091
2023	17.02	2.96	1.91	0.0093	-0.00088
2022	21.96	3.27	2.72	-0.0085	-0.00106
2021	17.08	1.89	2.76	0.0219	−0.00084
2020	18.16	1.71	3.76	0.0090	−0.00096
2019	16.96	2.51	2.38	0.0104	−0.00088
2018	14.61	2.53	1.65	0.0080	−0.00077
2017	16.17	2.61	1.87	0.0142	−0.00082
2016	14.87	2.31	2.10	0.0048	−0.00082
2015	15.80	2.30	2.24	0.0103	−0.00083
2014	22.34	2.38	3.79	0.0264	−0.00110
2013	17.99	1.66	3.30	0.0228	−0.00090
2012	17.44	1.72	3.04	0.0230	−0.00085
2011	18.37	2.15	2.97	0.0194	−0.00091
2010	14.41	1.85	2.31	0.0100	−0.00076
2009	11.36	1.20	1.99	0.0119	−0.00062
2008	17.44	1.57	3.89	0.0028	−0.00094
2007	18.04	1.47	3.51	0.0236	−0.00084
2006	11.89	1.33	2.09	0.0097	−0.00063

Forecast					
2025 CM$	19.00	2.90	2.60	0.0105	-0.00090
2021 CM$	16.50	2.10	2.60	0.0135	−0.00085

[1] SCC = somatic cell count; see SCS section for a fuller explanation of quality premiums

Milk prices 2021-24 averaged $18.61 for class III compared to the forecast price of $16.50 used in 2021 NM$ (VanRaden et al., 2021); the average 2024 price as of September is $18.37. Future contract prices average about $21.75 for the final months of 2024 and $19.50 for 2025; the USDA World Agricultural Supply and Demand Estimates Report (WASDE) 2025 forecast price for Class III milk is $18.95.

Butterfat prices 2021-24 averaged $2.88 and were above the $2.10 forecast in 2021 whereas protein prices averaged only $2.27 and were below the $2.60 forecast in 2021. The 2024 component prices as of September averaged $3.38 for butterfat and $1.68 for protein. Demand for butterfat has increased after trans fats were banned as an ingredient in food (U.S. Food and Drug Administration, 2015), and prices for butterfat continue to surge relative to protein. During 2020 the milk and component prices varied wildly as markets shifted between restaurant and grocery store demands.

Predicted prices used in CM$ are now $2.90 for fat and $2.60 for protein. Fluid milk processors usually pay no premium for extra protein because grocery store milk is not yet labeled or priced by protein content, but a protein premium is included in FM$ to prevent the actual value of protein from becoming negative after feed costs are subtracted. Selection on FM$ is appropriate mainly in southeastern states or in countries that do not yet pay for protein.

The value of protein in NM$ represents an average across milk markets of price formulas paid to U.S. producers. Before 2014, NM$ was a weighted average of prices paid by processors for four usage classes: 1) fluid milk, 2) soft/frozen products, 3) hard cheese, and 4) butter/powdered milk. That approach was used since the milk-fat-protein dollars (MFP$) index was first introduced (Norman et al., 1979) and is still used to charge processors in Federal Orders. However, most Federal Orders ignore the actual usage of milk when paying producers and instead pay component prices to producers as if all milk is used for cheese. Cheese yield and protein pricing was assumed for 80% (previously 92%) of U.S. milk because only 68% (Agricultural Marketing Service, 2022) to 75% (NMPF, 2023) is sold within the Federal Orders, and other processors may pay smaller premiums for protein.

Historical component and milk prices after deducting hauling charge used since 1977 to calculate NM$ and MFP$ follow:

Year	Milk	Fat	True protein	Volume
1977	12.30	1.48	1.24	0.034
1978	12.23	1.51	1.18	0.034
1979	12.25	1.52	1.21	0.033
1980	12.32	1.61	1.26	0.029
1981	12.35	1.63	1.28	0.028
1982	12.24	1.64	1.30	0.026
1983	12.34	1.70	1.33	0.024
1984	12.32	1.75	1.33	0.022
1985	12.26	1.72	1.28	0.024
1986	12.35	1.85	1.29	0.020
1987	12.28	1.74	1.23	0.025
1988	12.26	1.68	1.26	0.026
1989	12.31	1.46	1.50	0.027
1990	12.33	1.13	1.39	0.042
1991	12.23	1.12	1.47	0.039
1992	12.29	0.79	1.54	0.049
1993	12.33	0.70	1.66	0.049
1994	12.24	0.58	1.57	0.055
1995	12.29	0.72	1.69	0.047

Year	Milk	Fat	True protein	Volume
1996	12.27	0.89	1.65	0.042
1997–99	12.30	0.80	2.12	0.031
2000–03	12.68	1.15	2.55	0.010
2003–06	12.70	1.30	2.30	0.013
2006–09	12.70	1.50	1.95	0.016
2010–13	14.36	1.63	1.94	0.029
2014–16	17.43	1.95	2.48	0.032
2017	16.93	2.00	2.32	0.030
2018–20	16.43	2.10	2.17	0.026
2021-24	15.93	2.10	2.39	0.024
2025	18.50	2.90	2.08	0.026

Component prices were previous-year average prices until 1997, when averages over several years were used in forecasting. Crude protein prices reported prior to 2000 were converted to true protein prices by multiplying by 1.064. Milk prices paid to producers were stable from 1977 through 2010 when much inflation occurred in labor, feed, and many other input prices. Additional history on economic indexes is provided in the NM$ history section.

SCS

Lower PTA SCS gives higher milk prices in markets where quality premiums are paid. Somatic cell premiums and penalties in Federal orders for class III milk for the last 4 years averaged a price increase of $0.0009 for each 1,000 cell/ml decrease in SCC. Premiums are converted from SCC scale to SCS scale by dividing by 0.0072, which is the difference between log base 2 of 201,000 and log base 2 of 200,000, the assumed average of SCC. The value of SCC/100 pounds of milk is now converted to the value of SCS as $0.0009/0.0072 = $0.125.

Actual changes in SCC from a 1-unit change in PTA SCS (a doubling of SCC) and actual SCC differences among bull daughters are now much less than when SCC premiums were introduced because average SCC is much lower than in past decades. The actual value of PTA SCS is higher for herds with more MAST and lower for herds with less MAST because payments are linear with SCC rather than with SCS. Until 2018, the value assigned to SCS in the NM$ formula included correlated costs of MAST, but those costs are now assigned directly to the MAST PTA.

Different premiums for SCS are applied in each index. The full class III premium is applied to SCS in CM$ because manufacturing plants typically provide incentives for improved milk quality. The premium in NM$ uses the assumption that 80% of the milk will be sold in blend markets that are paid the class III premium. Because some producers in fluid markets receive premiums for improved milk quality, 50% of the premium was assigned to SCS in FM$. The actual value of reduced SCS in fluid milk is substantial because of improved shelf life and taste (Ma et al., 2000).

PL and LIV

The trait PL measures how long cows stay in the herd by summing lactation credits from first calving until the cow is sold for beef or dies on the farm. Cows sold for dairy purposes are given partial credit as of the date sold, and their future PL is projected, the same as for cows still alive on the farm. The lactation curve credits give more credit to months of peak lactation, more credit to mature-cow lactations, and no credit to dry periods, with an average credit of 10 months for a 305-day lactation. Cow LIV measures only the on-farm death loss per lactation expressed as the percentage of additional cows that live so that positive numbers are favorable.

The economic value of PL accounts for maturity effects by assuming differing profits for each parity and accounts for genetic progress by assuming that the merit of replacement heifers improves in each subsequent year. Faster genetic gain makes young cows more valuable relative to older cows, and NM$ now accounts for the improvement of lifetime NM$ of $60 per year for transmitting ability or $120 for breeding value following methods recommended by Schmitt et al. (2019) and De Vries (2017).

Instead of simply multiplying average profit by number of lactations as in the previous NM$ formula, adjusted profit is now summed across parities with the fraction of cows in each parity calculated as $[1 - 1/(2.69 + PL/10)]^{parity-1}$ except that parities after fifth were summed and treated the same as fifth. Average profit is adjusted for NM$ trend, higher mature yield, higher maintenance cost at mature weights, and higher compound interest charges for later lactations. Those adjustments estimate highest profits in the third and fourth parities and more profit as a function of PL than previously assumed and an increased emphasis on PL. Adjusted profits follow:

Parity	Herd fraction (%)	Average profit ($)	NM$ trend ($)	Mature yield ($)	Mature weight ($)	Compound interest ($)	Adjusted profit ($)[1]
1	37.1	67	76	−394	129	−8	−80
2	23.3	67	31	0	0	−3	145
3	14.7	67	−13	151	−73	1	183
4	9.2	67	−58	205	−96	6	175
5+	15.7	67	−102	205	−107	10	124

[1] Sum of NM$ trend, mature yield, mature weight, and compound interest plus a constant of $299 so that average profit weighted by fraction of cows in each parity equals $67

The SD of PL earlier increased in the 2006 revision by 40% when including the months in milk beyond 7 years of age and beyond 305 days per lactation using credits determined from lactation curves (VanRaden et al, 2006). Those extra credits for higher mature-lactation yield accounted for 6% of the SD increase and were removed by dividing the PL economic value by 1.06 when recalculating economic value based on lactation profit instead of lactation yield.

Cow LIV was included as a new trait in April 2017. Cows that die or are euthanized on the farm generate no beef income and may have more health expenses than cows that are culled. The value of PL was reduced at that time because the loss of beef income is now directly tied to cow LIV rather than indirectly to PL. Cows that die are assumed to generate $1425 less income than those sold for beef calculated as 1,500 pounds times $0.90/pound plus $75/death for on-farm labor and cow disposal charges. Because PTA LIV is expressed as the percentage of deaths per lifetime, the economic value is $1425(0.01) = $14.25.

Replacement costs now are assumed to include a newborn 90-pound heifer price of $400, a cost of $0.85/pound of growth, and a fixed cost of $450 for a total of $1,794 to raise the heifer to 1,200 pounds. The interest rate also remains at 5%. Relative emphasis decreased for PL and increased for LIV because of these income and cost adjustments.

Type traits

[This section was from 2021 but the Jersey udder composite may be revised in 2025.] Linear type traits provide additional information about incomes and expenses. Instead of directly using PTAs for all type traits, composites are used in NM$. For Holsteins, UDC, FLC, and BWC are calculated by Holstein Association USA (Holstein Association USA, 2017). For other breeds, published PTAs for linear traits are converted to standardized transmitting abilities by dividing by TTA SD and then are combined into composites that are not released. Estimated genetic SDs follow:

Trait	SD					
	Ayrshire	Brown Swiss	Guernsey	Holstein	Jersey	Milking Shorthorn
Stature	1.7	1.3	2.0	1.0	1.1	1.3
Strength	1.0	0.7	1.2	1.0	0.7	0.8
Body depth	0.9	0.9	1.4	1.0	…	1.0
Dairy form	0.8	0.9	1.5	1.0	0.7	1.1
Rump angle	1.0	0.9	1.4	1.0	0.8	1.1
Thurl width	1.0	0.7	1.3	1.0	0.7	0.8
Rear legs (side view)	0.7	0.7	0.7	1.0	0.6	0.5
Rear legs (rear view)	1.0	0.3	0.6	1.0	1.0	0.7
Foot angle	0.7	0.7	0.7	1.0	0.5	0.7
Feet & legs score or mobility	…	1.0	…	1.0	…	…

Trait	SD					
	Ayrshire	Brown Swiss	Guernsey	Holstein	Jersey	Milking Shorthorn
Fore udder	1.0	1.0	1.3	1.0	0.9	0.7
Rear udder height	1.1	0.9	1.2	1.0	0.9	1.0
Rear udder width	0.9	0.8	1.3	1.0	0.8	0.8
Udder cleft	0.9	0.8	1.0	1.0	0.7	0.6
Udder depth	1.0	0.9	1.4	1.0	1.2	0.9
Teat placement	1.0	1.0	1.2	1.0	0.9	1.0
Teat length	1.2	1.3	1.5	1.0	0.8	1.4
Rear teat placement	…	…	…	1.0	1.5	…
Rear teat placement (side view)	…	…	…	…	0.9	…
Milking speed	…	5.0	…	…	…	…

Relative values of udder and feet/legs traits for Jerseys, Guernseys, and Brown Swiss are obtained from the official Functional Trait Indexes or Functional Udder Indexes of those three breed associations. Jersey values are applied to Ayrshires and Milking Shorthorns. Breed association Functional Trait Index formulas were obtained from correlations with PL, but partial regressions are difficult to estimate in small populations with many traits.

Udder. The formula for Holstein UDC was updated by Holstein USA in August 2017 (Holstein USA, 2017) and applied in merit indexes in December 2017. The Holstein UDC now adjusts for the correlated influence of stature, and intermediate optima are assigned for both teat length and rear teat placement. Current relative weights used for merit index calculations are:

Trait	Relative value (%)			
	Holstein	Brown Swiss	Guernsey	Jersey and other breeds
Stature	−20	…	…	…
Fore udder	16	21	15	7
Rear udder height	23	6	15	33
Rear udder width	19	1	5	19
Udder cleft	8	2	15	1
Udder depth	20	35	33	31
Teat placement	4	11	15	4
Rear teat placement (nonlinear)	5	…	…	…
Teat length	5	−24	−2	4
UDC	…[1]	100	100	100

[1] Holstein values are weights (expressed as percentages) from composite formula calculated by Holstein Association USA (2017) and, therefore, do not sum to 100

Milking speed is evaluated for Brown Swiss and rear teats (side view) is evaluated for Jerseys, but those traits [not shown in table] are not evaluated for other breeds.

Feet/legs. The formula for Holstein FLC was updated by Holstein USA in August 2017 (Holstein USA, 2017) and applied in merit indexes in December 2017. The Holstein FLC now adjusts for the correlated influence of stature. Because rear legs (rear view) and feet & legs score are not available for breeds other than Holstein, STAs for foot angle and rear legs (side view) are included in the FLCs for other breeds. Current relative weights used for merit index calculations are:

Trait	Relative value (%)			
	Holstein	Brown Swiss	Guernsey	Jersey and other breeds
Stature	−17	…	…	…
Rear legs (side view)	…	−32	−16	−30
Rear legs (rear view)	18	…	36	…
Foot angle	8	68	48	70
Feet & legs score	58	…	…	…
FLC	…[1]	100	100	100

[1] Holstein values are weights (expressed as percentages) from composite formula calculated by Holstein Association USA (2017) and, therefore, do not sum to 100

Body size/weight. Since April 2017, BWC replaced the previous body size composite formula used in NM$ from 2000 through 2016. Research by Holstein Association USA (2016) used recent weight and linear type data from the research herds that also measured feed intake to predict BW more accurately. In December 2017, a new BWC was introduced for Jerseys based on research by the American Jersey Cattle Association and the University of Wisconsin (American Jersey Cattle Association, 2017). The Jersey BWC was also used for Brown Swiss because neither breed scores body depth. Holstein BWC is used for breeds other than Jersey and Brown Swiss. Current relative weights for combining the linear traits into BWC are:

Trait	Relative value (%)	
	Jersey and Brown Swiss	Holstein and other breeds
Stature	28	23
Strength	28	72
Body depth	…	8
Dairy form	−35	−47
Rump width	9	17
BWC	100	…[1]

[1] Holstein values are weights (expressed as percentages) from composite formula calculated by Holstein Association USA (2017) and, therefore, do not sum to 100

The genomic regression of BW on BWC EBV was estimated from Holstein research cows to be 15.7 kg BW = 35 pounds BW per unit of BWC compared with 40 pounds from a phenotypic regression of Manzanilla-Pech et al. (2016) used previously in NM$.

Derivation of the economic value of BWC is in the feed saved section.

Calving ability

Calves that are born with difficulty or die reduce dairy farm profit. Because calving ease and stillbirth effects from the service sire and the dam differ, CA$ includes 4 traits: service-sire calving ease (SCE), daughter calving ease (DCE), service-sire stillbirths (SSB), and daughter stillbirths (DSB). Many other countries use the terms direct and maternal or paternal and maternal instead of service sire and daughter. Comparisons of evaluations can be confusing because of terminology, direction of scales, and evaluation of pure maternal effects by several countries with an animal model instead of a sire-maternal grandsire (MGS) model. The NM$ index has included calving ease since 2003 (VanRaden and Seykora, 2003) and stillbirth since 2006 (Cole et al., 2007) The CA$ index combines these traits and is included in NM$ but not released directly.

Economic values for stillbirths of Holsteins were derived as follows. Value of 2-day-old calves was assumed to be $400 for both bulls and heifers. The SSB and DSB evaluations are percentages of calves that die as compared with the bases of 5.6 and 6.6%. Lifetime value of a 1% decrease in DSB is 2.7 lactations multiplied by average calf value: 2.7($400)/100 = $10.80. For SSB, this value must be halved because SSB measures the full effect of the service sire, whereas DSB measures only half of the dam's effect. Other breeds had insufficient data to begin stillbirth evaluations.

The value of DCE includes $70 per difficult birth (score 4 or 5) for farm labor and veterinary charges as well as a 1.5% increased probability of cow death multiplied by $2,038. Those expenses are multiplied by 2 because scores 2 and 3 contribute additional smaller effects that occur more frequently. Difficulty in later parities is 0.3 as great, which results in a lifetime incidence of $1+(0.3 \times 1.8) = 1.5$. Total value of DCE is $([\$70 + (0.015 \times \$2{,}038)] \times 2 \times 1.5)/100 = \$3.02$.

The value of SCE also includes losses in the bull's mates of \$133 for yield and \$75 for fertility and longevity. Difficult births reduce 305-day milk yield by 700 pounds and delay the bull's mates from becoming pregnant again by 20 days on average. Such losses are not charged to DCE because the bull's daughter evaluations for yield, fertility, and longevity already account for them. The value of SCE must be halved as done for SSB. Total value of SCE is $([\$70 + (0.015 \times \$2{,}038) + \$133 + \$75] \times 2 \times 1.5)/2 \times 100 = \$4.63$. Values were then rounded to \$5 for SCE, \$3 for DCE, \$4 for SSB, and \$11 for DSB. The units of CA\$ are the lifetime dollar value that the calving traits contribute to NM\$. Calculation requires subtracting trait averages, multiplying by economic values, and reversing direction to obtain net benefit instead of net cost:

$$\text{CA\$} = -5(\text{SCE} - 2.2) - 3(\text{DCE} - 2.7) - 4(\text{SSB} - 5.6) - 11(\text{DSB} - 6.6).$$

For Brown Swiss, both the SCE and DCE averages are 2.9, and the economic values are −6 for SCE and −8 for DCE because separate stillbirth evaluations are not available and calving ease values include the correlated response in stillbirth:

$$\text{CA\$}_{\text{Brown Swiss}} = -7(\text{SCE} - 2.9) - 8(\text{DCE} - 2.9).$$

For Holsteins, the TTA SDs are 1.7 for SCE, 1.4 for DCE, 1.0 for SSB, and 1.7 for DSB with corresponding relative emphasis of 24, 12, 11, and 53% in CA\$. The CA\$ SD is \$18, and the relative emphasis on calving traits in NM\$ is 3.3%. Cows that are not genotyped do not have PTAs available to compute CA\$ because a sire-MGS model (instead of an animal model) is used for evaluation of CA\$ traits. Therefore, a pedigree index (0.5 sire PTA + 0.25 MGS PTA + 0.125 maternal great-grandsire PTA, etc.) is substituted for PTA for all generations of the maternal line; breed average replaces any unknown ancestors.

Mating programs should assign bulls with low and high PTAs for service-sire effects to heifers and cows, respectively. The economic value used in NM\$ is a weighted average of losses for cows and heifers. Thus, when ranking sires for heifer use, another \$4 should be subtracted from NM\$ for each percentage of SCE, and \$2 for each percentage of SCE should be added back to NM\$ when ranking service sires for cows. These minor adjustments for the differing economic values in heifer versus cow matings can be handled with computerized mating programs.

Lifetime profit

The NM\$ index is defined as expected lifetime profit as compared with the breed base cows born in 2020. Incomes and expenses that repeat for each lactation are multiplied by the cow's expected number of lactations. This multiplication makes the economic function a nonlinear function of the original traits. For official NM\$, a linear approximation of this nonlinear function is used as recommended by Goddard (1983). The linear function is much simpler to use and was correlated with the nonlinear function by 0.999.

Index selection based on computer calculation is efficient, and computer mating programs that account for inbreeding using complete pedigrees also should be used. Selection and mating programs both can have large, nearly additive effects on future profit. Gains from mating programs do not accumulate across generations, whereas gains from selection do. Cows and bulls within each breed are ranked with the same NM\$ even though the timing of gene expression differs by sex.

The NM\$ measures additional lifetime profit that is expected to be transmitted to an average daughter but does not include additional profit that will be expressed in granddaughters and more remote descendants. Gene flow methods and discounting of future profits could provide a more complete summary of the total profit from all descendants. Animal welfare may be a goal of society but is not assigned a monetary value in NM\$. Healthier cows can make dairying a more enjoyable occupation, and traits associated with cow health may deserve more emphasis as labor costs increase. Production of organic milk with fewer treatment options could require cows with more natural ability to resist disease and remain functional.

The profit function approach used in deriving NM\$ lets breeders select for many traits by combining the incomes and expenses for each trait into an accurate measure of overall profit. Averages and SDs of the various traits in the profit function may differ by breed, but official NM\$ is calculated by using Holstein values instead of having a slightly different NM\$ formula for each breed. Producers should use the lifetime merit index (NM\$, CM\$, FM\$, or GM\$) that corresponds to the market pricing that they expect a few years in the future when buying breeding stock and 5 years in the future when buying semen.

History and future of NM$

Current and previous NM$ changes can be quickly summarized as:

Year	Correlation between new and previous NM$	New traits
2025	0.992	None
2021	0.981[1]	FSAV, EFC, HLIV
2018	0.994	MFEV, DA, KETO, MAST, METR, RETP
2017	0.989	LIV
2014	0.965	HCR, CCR
2010	0.990	None
2006	0.975	Stillbirth, revised PL scaling
2003	0.970	DPR, calving ease
2000	0.931	Type composites (UDC, FLC, BWC)
1994	0.888	PL, SCS

[1] Correlation for young bulls = 0.992

The 2025 NM$ index with updated economic values is correlated with the 2021 NM$ formula by 0.992. An increase in genetic progress worth $8 million/year is expected on a national basis, assuming that all changes are improvements and that all breeders select on NM$. The 2021 NM$ formula included new traits FSAV, EFC, and HLV and was correlated by 0.981 with the previous index. The 2018 NM$ index included 6 new health traits and was correlated by 0.994 with the 2017 NM$ index (VanRaden, 2017). The 2017 index included the new trait LIV and was correlated by 0.989 with the 2014 NM$ index (VanRaden and Cole, 2014) for recent progeny-tested bulls. The 2014 NM$ index, which included new traits HCR and CCR, was correlated by 0.965 with the 2010 NM$ index (Cole et al., 2009). The 2010 NM$ index was correlated by 0.99 with the 2006 NM$ formula (VanRaden and Multi-State Project S-1008, 2006); the 2010 changes were mostly caused by an increase in the price of feed, decrease in the value of heifer calves, and higher cost of raising replacements, but no new traits. The 2006 NM$ index was correlated by 0.975 with the 2003 NM$ formula (VanRaden and Seykora, 2003) for recent progeny-tested bulls; about half the changes were caused by the PTA PL revision and the rest from addition of stillbirth and updates of trait economic values.

In the 2003 NM$ revision (VanRaden and Seykora, 2003), cow fertility and calving ease were incorporated into NM$. In the 2000 NM$ revision (VanRaden, 2000), type traits were included along with yield and health traits using a lifetime profit function based on research of scientists in the S-284 Health Traits Research Group. Before 2000, breed association indexes had included type traits but not health traits, and NM$ had included health traits but not type traits. In 1994, PL and SCS were combined with yield traits into NM$ using economic values that were obtained as averages of independent literature estimates (VanRaden and Wiggans, 1995).

In the 1980s as part of Project NC-2 of the North Central Regional Association of Agricultural Research Experiment Station Directors, researchers developed a profit function to compare genetic lines in their experimental herds:

$$\begin{aligned}\text{lifetime profit} = {} & \text{milk value} + \text{salvage value} + \text{value of calves} \\ & - \text{rearing cost} - \text{feed energy} - \text{feed protein} - \text{health cost} - \text{breeding cost.}\end{aligned}$$

Relative net income also was developed to measure profit from field data with adjustment for opportunity cost to more fairly compare short- and long-term investments (Cassell et al., 1993). The main difference between NM$ and the profit function approaches is that a PTA is calculated for each evaluated trait and then combined instead of combining each cow's phenotypic data directly. The PTA approach is more accurate because heritabilities of traits differ, genetic correlations are not the same as phenotypic correlations, and all phenotypes are not available at the same time.

In 1984 and 1977, economic index formulas based on cheese yield price (CY$) and protein price (MFP$), respectively, were introduced. In 1971, USDA introduced its first genetic-economic index called predicted difference dollars (PD$), which combined only milk and fat yields. The three different milk pricing formulas (Norman, 1986) continued to be released until 1999 when they were replaced by the more complete merit indexes CM$, NM$, and FM$, respectively (see the yield traits section for a history of milk price formulas).

A history of the changes in relative values for traits included in the U.S. indexes follows:

Traits included	PD$ (1971)	MFP$ (1976)	NM$ (1994)	NM$ (2000)	NM$ (2003)	NM$ (2006)	NM$ (2010)	NM$ (2014)	NM$ (2017)	NM$ (2018)	NM$ (2021)	NM$ (2025)
Milk	52	27	6	5	0	0	0	−1	−1	−1	0	3
Fat	48	46	25	21	22	23	19	22	24	27	22	25
Protein	…	27	43	36	33	23	16	20	18	17	17	11
PL	…	…	20	14	11	17	22	19	13	12	15	12
SCS	…	…	−6	−9	−9	−9	−10	−7	−7	−4	−3	-3
BSC/BWC	…	…	…	−4	−3	−4	−6	−5	−6	−5	−9	-11
UDC	…	…	…	7	7	6	7	8	7	7	3	1
FLC	…	…	…	4	4	3	4	3	3	3	1	1
DPR	…	…	…	…	7	9	11	7	7	7	5	3
CA$	…	…	…	…	…	6	5	5	5	5	3	3
HCR	…	…	…	…	…	…	…	1	1	1	1	1
CCR	…	…	…	…	…	…	…	2	2	2	1	2
LIV	…	…	…	…	…	…	…	…	7	7	4	6
HTH$	…	…	…	…	…	…	…	…	…	2	2	2
RFI	…	…	…	…	…	…	…	…	…	…	−12	-14
EFC	…	…	…	…	…	…	…	…	…	…	1	1
HLIV	…	…	…	…	…	…	…	…	…	…	1	1

Emphasis on yield traits has declined as other fitness traits were introduced. As protein yield became more important, milk volume became less important because of the high correlation of those two traits. A more complete history and comparisons with selection indexes used by other countries are available (Shook, 2006; VanRaden, 2002; VanRaden, 2004).

Future selection indexes and potential for future genetic progress have also been forecast by Cole and VanRaden (2018).

Acknowledgments

The authors thank many university researchers for development of this and previous NM$ revisions, industry experts for helpful discussion of income and expense formulas, Council on Dairy Cattle Breeding and Animal Genomics and Improvement Laboratory staff with special thanks to Mahesh Neupane for review and revision of the research report. The AGIL authors were supported by appropriated project 8042-31000-002-00-D, “Improving Dairy Animals by Increasing Accuracy of Genomic Prediction, Evaluating New Traits, and Redefining Selection Goals,” of the USDA Agricultural Research Service. The USDA is an equal opportunity provider and employer.

Abbreviations

BW = body weight
BWC = body weight composite
CA$ = calving trait subindex
CCR = cow conception rate
CM$ = cheese merit index
CY$ = cheese yield index
DA = displaced abomasum
DCE = daughter calving ease
DMI = dry matter intake
DPR = daughter pregnancy rate
DSB = daughter stillbirth
ECM = energy-corrected milk
EFC = early first calving
FLC = feet/leg composite
FM$ = fluid merit index
FSAV = feed saved
GM$ = grazing merit index,
HCR = heifer conception rate
HLIV = heifer livability
HTH$ = health trait subindex
KETO = ketosis
LIV = cow livability
MAST = clinical mastitis
MBW = metabolic body weight
METR = metritis
MFEV = milk fever (hypocalcemia)
MGS = maternal grandsire
MFP$ = milk-fat-protein index
NE_L = net energy of lactation
NM$ = lifetime net merit index
PD$ = predicted difference milk-fat index
PL = productive life
PTA = predicted transmitting ability
REL = reliability
RETP = retained placenta
RFI = residual feed intake
SCC = somatic cell count
SCE = service-sire calving ease
SCS = somatic cell score
SD = standard deviation
SSB = service-sire stillbirth
TTA = true transmitting ability
UDC = udder composite
WASDE =world agricultural supply and demand estimates

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