AUTOMATED ACTIVITY MEASURING ADOPTION AND ECONOMIC CONCERNS

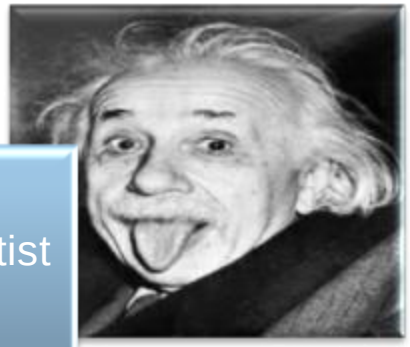
UK UNIVERSITY OF KENTUCKY College of Agriculture

PRECISION DAIRY & COW ENVIRONMENT CONSORTIUM

Jeffrey Bewley, Amanda Sterrett, Randi Black, Barbara Wadsworth, Di Liang, Karmella Dolecheck, Matthew Borchers, Lauren Mayo, Nicky Tsai, Maegan Weatherly, Melissa Cornett, Samantha Smith, Megan Hardy, and Jenna Klefot

Precision Dairy Players

Scientist



Engineer

Company

Farmer

Cow

These Two are the Keys

Technological Transformation

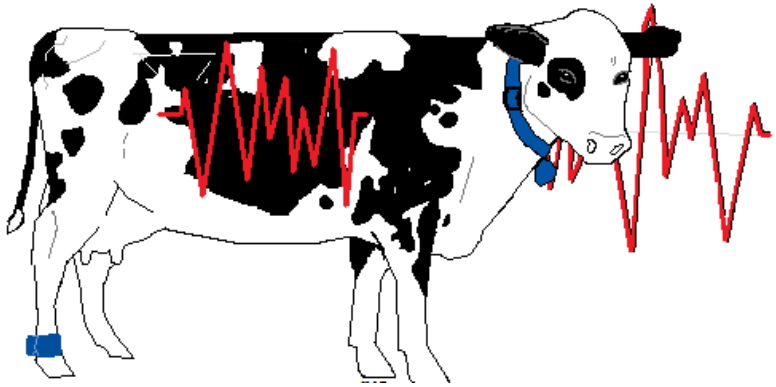
- Extension of other industries
- New dairy industry demands
  - Animal well-being
  - Consumer demands
  - Environmental pressure
  - Labor challenges
  - Economic competition

Cow Challenge Solutions

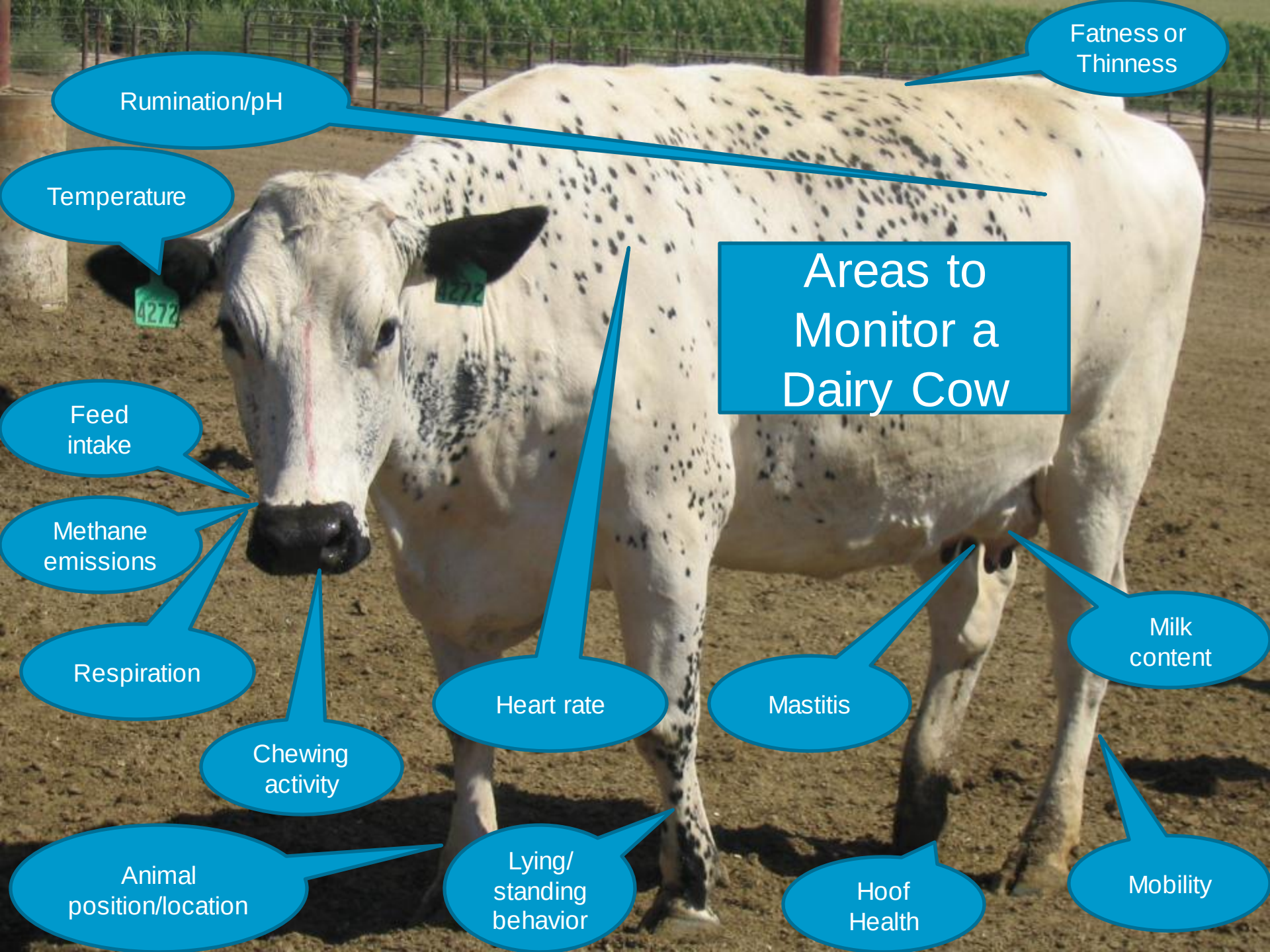
1. Finding cows in heat
2. Finding and treating lame cows
3. Finding and treating cows with mastitis
4. Catching sick cows in early lactation
5. Understanding nutritional status of cows
    a. Feed intake
    b. Body condition (fat or thin)
    c. Rumen health (pH/rumination time)

Happy Cows via Technology?

Precision Dairy Management



The use of automated, mechanized technologies toward refinement of dairy management processes, procedures, or information collection


Areas to Monitor a Dairy Cow
Rumination/pH
Fatness or Thinness
Temperature
Feed intake
Methane emissions
Respiration
Chewing activity
Heart rate
Mastitis
Milk content
Animal position/location
Lying/ standing behavior
Hoof Health
Mobility

UK Coldstream Dairy Monitoring Capabilities

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Thank You to All our Consortium Sponsors!

Technology	Parameter(s) Measured
SmartBow	Position, Movement
VelPhone	Calving Time, Vaginal Temperature
Alanya	Temperature, Lying Time, Activity, Locomotion, Behavior
AfiLab	Fat, Protein, Lactose
Pedometer Plus	Lying Time, Steps
HR Tag	Rumination Time, Neck Activity
Track-a-Cow	Lying Time, Time at Feedbunk
Mastiline	Somatic Cell Count
CowManager Sensoor	Rumination Time, Feeding Time, Ear Skin Temperature, Activity
IceQube	Lying Time, Steps, Locomotion
Anemon	Vaginal Temperature, Estrus
TempTrack	Reticulorumen Temperature
FeverTag	Tympanic Temperature
AccuBreed	Mounting Activity
CowScout	Leg Activity

Precision Dairy Farming Benefits

- Improved animal health and well-being
- Increased efficiency
- Reduced costs
- Improved product quality
- Minimized adverse environmental impacts
- More objective

So Many Options!!!!

Ideal Technology

- Explains an underlying biological process
- Can be translated to a meaningful action
- Cost-effective
- Flexible, robust, reliable
- Simple and solution focused
- Information readily available to farmer
- Commercial demonstrations

What Are the Limitations of Precision Dairy Farming?

PDF Reality Check

- Maybe not be #1 priority for commercial dairy producers (yet)
- Many technologies are in infancy stage
- Not all technologies are good investments
- Economics must be examined
- People factors must be considered

Technology Pitfalls

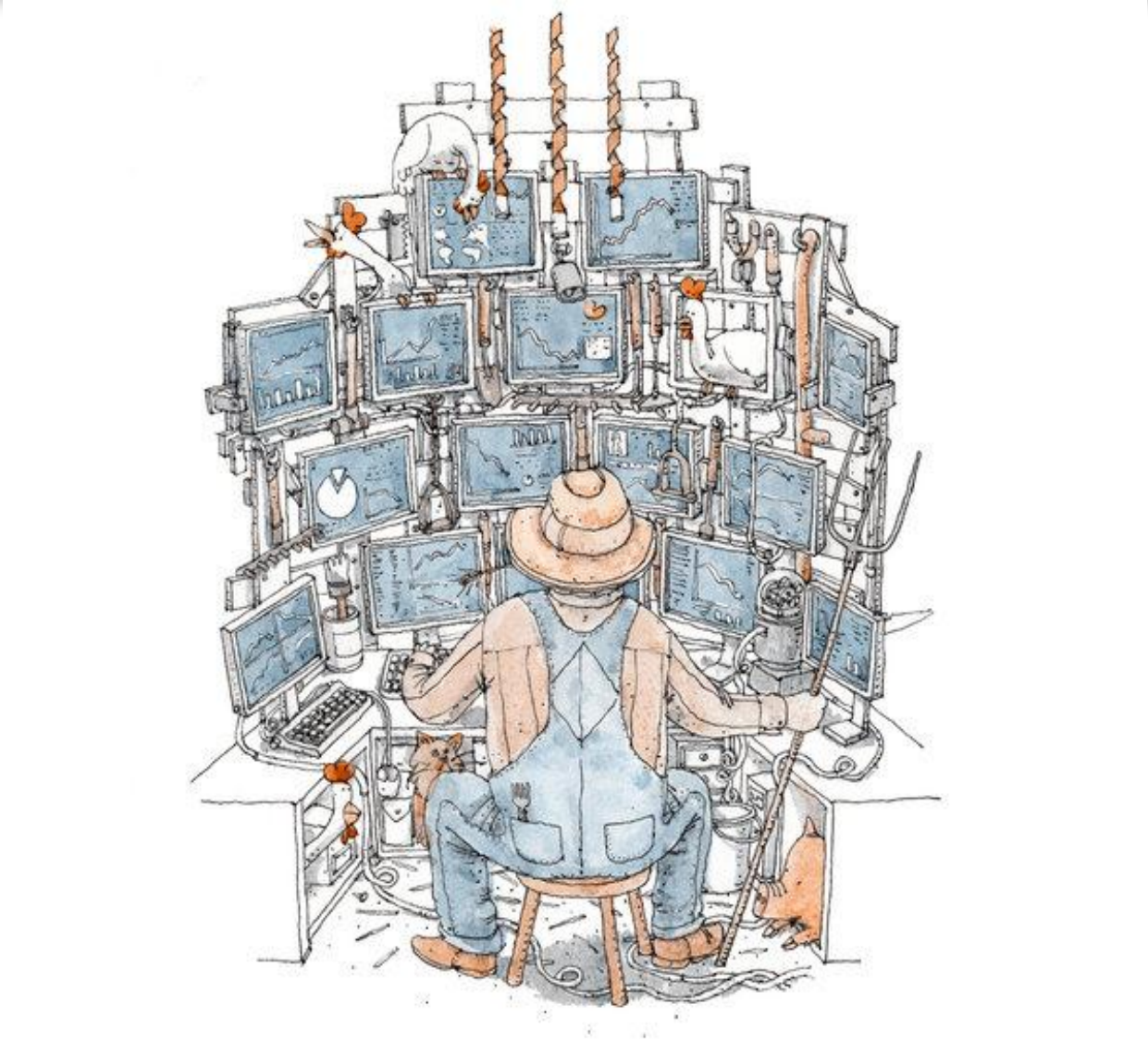
- “Plug and play,” “Plug and pray,” or “Plug and pay”
- Technologies go to market too quickly
- Not fully-developed
- Software not user-friendly
- Developed independently without consideration of integration with other technologies and farmer work patterns

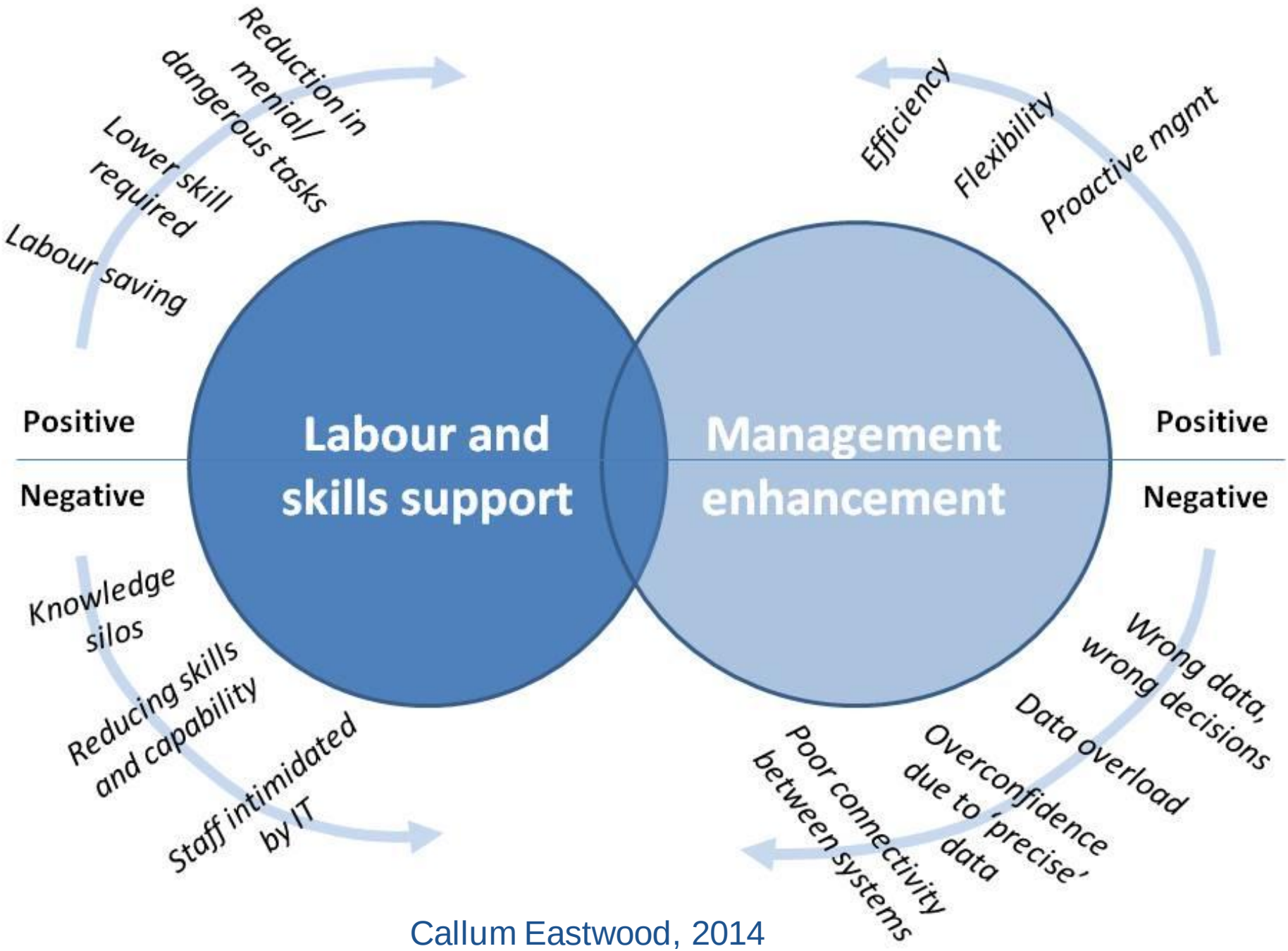
Technology Pitfalls

- Too many single measurement systems
- Lack of large-scale commercial field trials and demonstrations
- Technology marketed without adequate interpretation of biological significance of data
- Information provided with no clear action plan

- Be prepared for little things to go wrong
- Be careful with early stage technologies
- Need a few months to learn how to use data
- Data integration is challenging

UK Herdsman Office





Callum Eastwood, 2014

Accuracy and Precision

Sensitivity and Specificity

Sensitivity (true positive rate): alert with an observed mastitis case

$$Sensitivity = \frac{true\ positives}{true\ positives + false\ negatives}$$

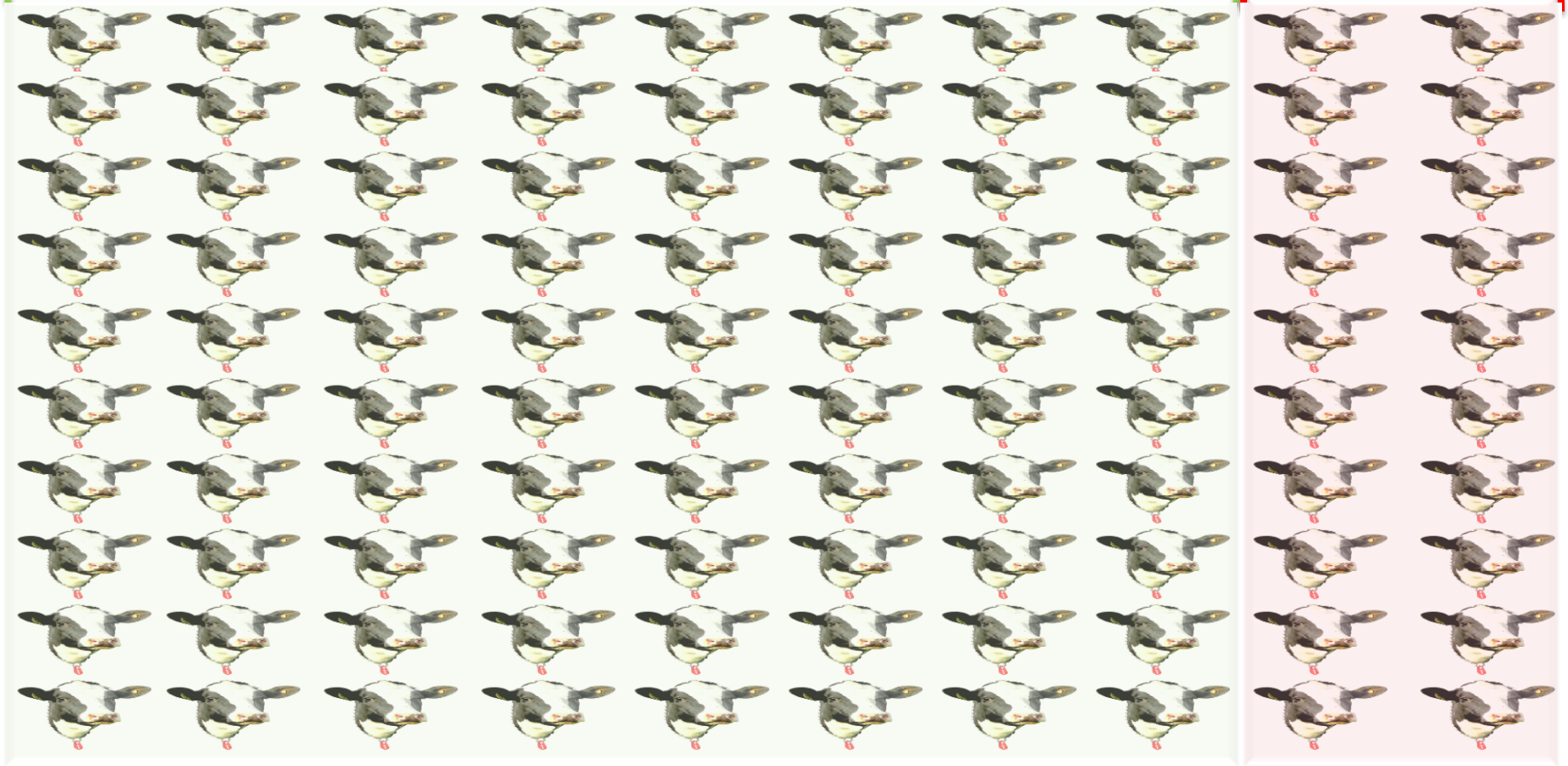
Specificity (true negative rate): no alert with no mastitis

$$Specificity = \frac{true\ negatives}{true\ negatives + false\ positives}$$

How Many Cows With Condition Do We Find?

80 Estrus Events Identified by Technology

20 Estrus Events Missed by Technology

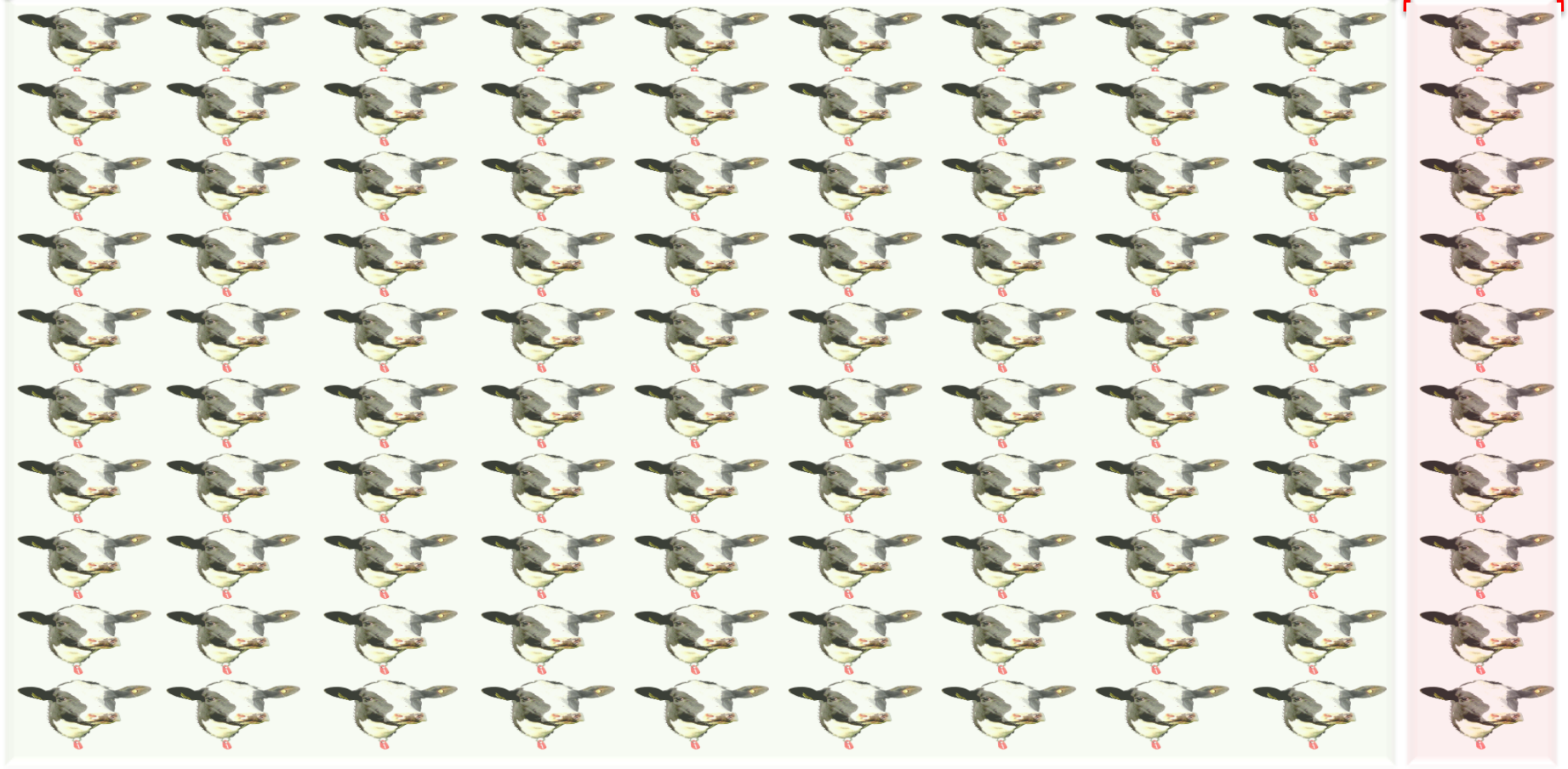


Example: 100 estrus events

How Many Alerts Coincide with an Actual Event?

90 Alerts for Cows Actually in Heat

10 Alerts for Cows Not in Heat



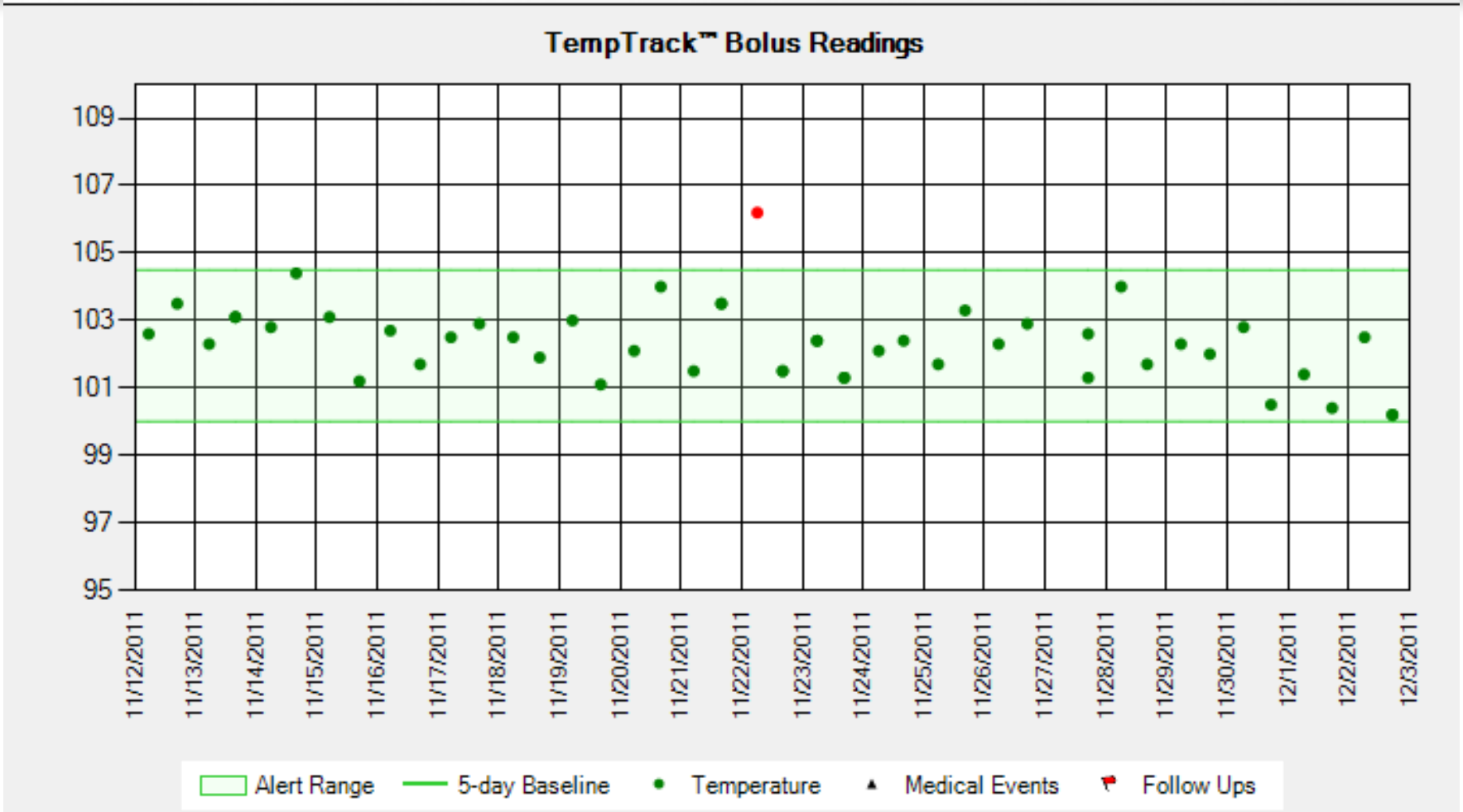
Example: 100 estrus events

What's the Sweet Spot?

- Cost of missed event
  - High for estrus
  - Lower for diseases?
- Cost of false positive
  - Low for estrus
  - High for mastitis
- Farm dependent


SMOKE
&
MIRRORS

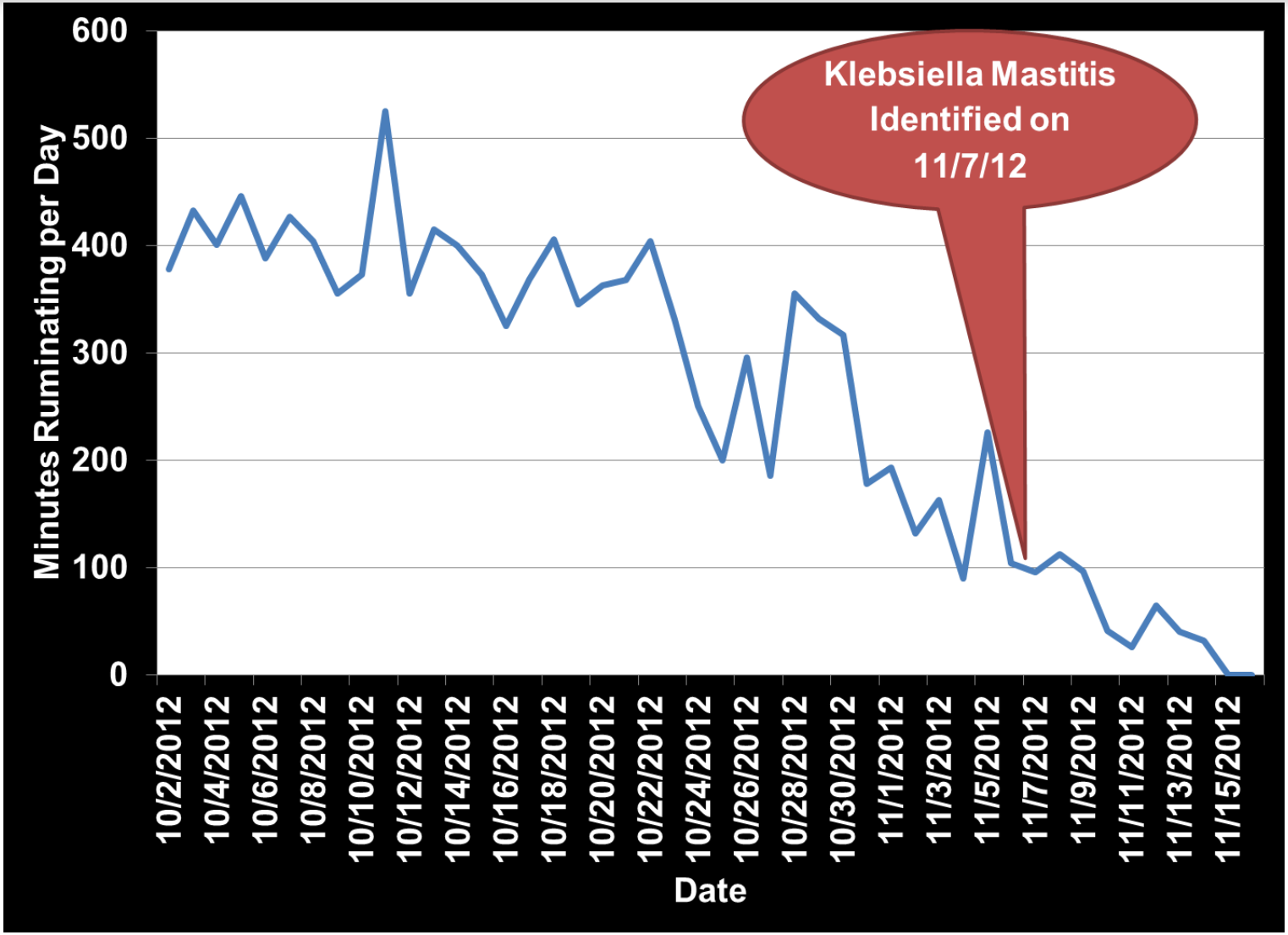
DVM TempTrack



1331 had *Strep uberis* isolated from her LF and RF quarters on 11/29/11

Amanda Sterrett et al. , Unpublished Data

SCR Rumination Time



Amanda Sterrett et al. , Unpublished Data

Percent of cows above and below Z-score thresholds and varying alert time windows from udder quarters from clinical, subclinical, and mastitis-free cows

			Subclinical mastitis		Clinical mastitis		No mastitis detected	
Z-score threshold	Observation window (d)	Variable monitored	% Below	% Above	% Below	% Above	% Below	% Above
-2	1	RU	45	55	49	51	54	46
-3	1	RU	45	55	49	51	54	46
-3	2	RU	46	54	49	51	54	46
-3	2	RU	46	54	49	51	54	46
-2	3	RU	48	52	46	53	56	44
-3	3	RU	47	53	48	52	55	45
-2	1	NA	45	55	49	51	54	46
-3	1	NA	45	55	49	51	54	46
-2	2	NA	46	54	49	51	54	46
-3	2	NA	46	54	49	51	54	46
-2	3	NA	48	52	48	52	56	44
-3	3	NA	47	53	48	52	55	45
-2	1	MY	4	96	22	78	35	65
-3	1	MY	4	96	21	79	35	65
-2	2	MY	7	93	25	75	35	65
-3	2	MY	7	93	25	75	35	65
-2	3	MY	15	85	29	71	38	62
-3	3	MY	15	85	29	71	37	63

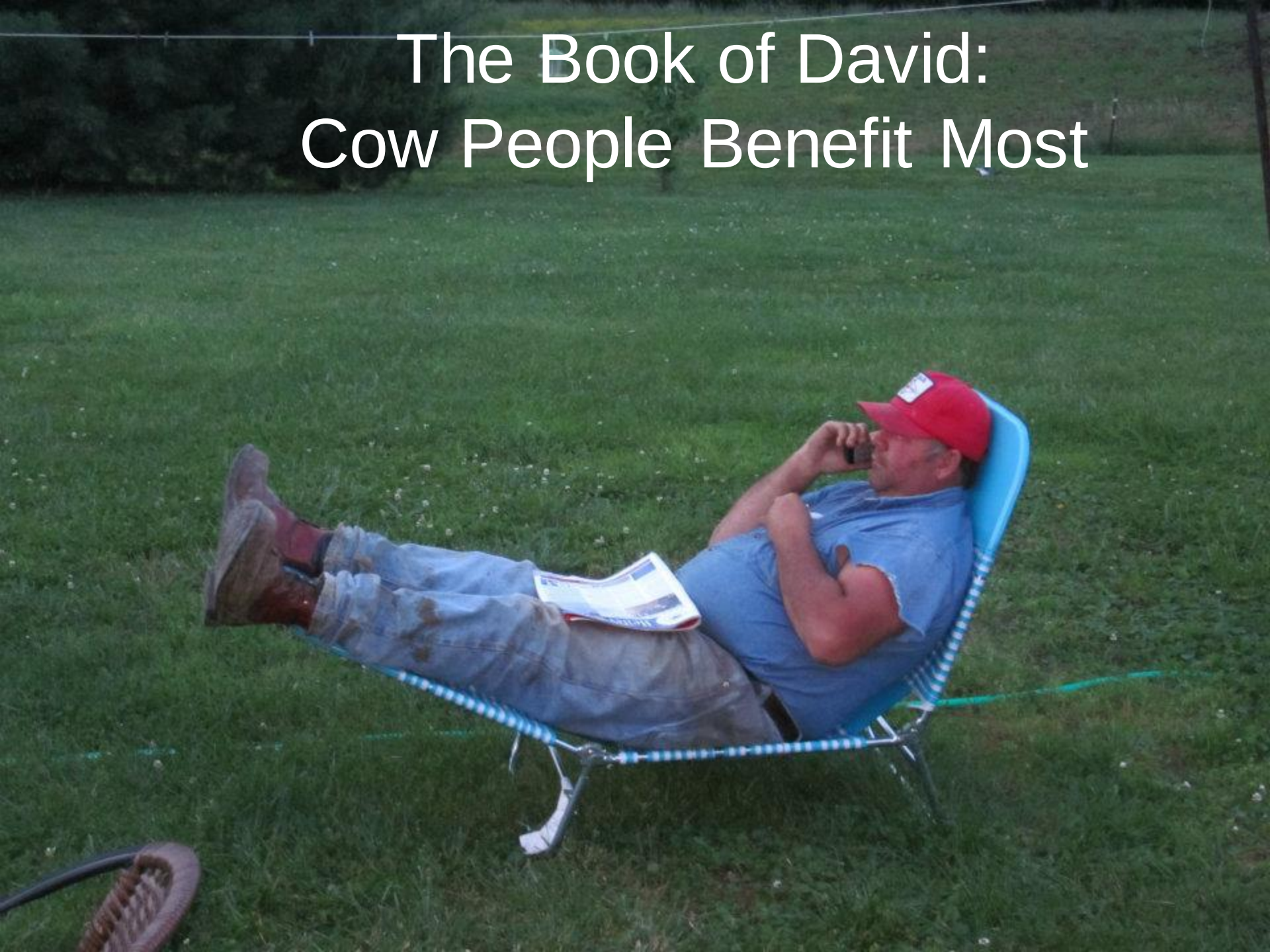
RU = rumination time, NA = neck activity, and MY = milk yield.

From Purdue to Poor Due

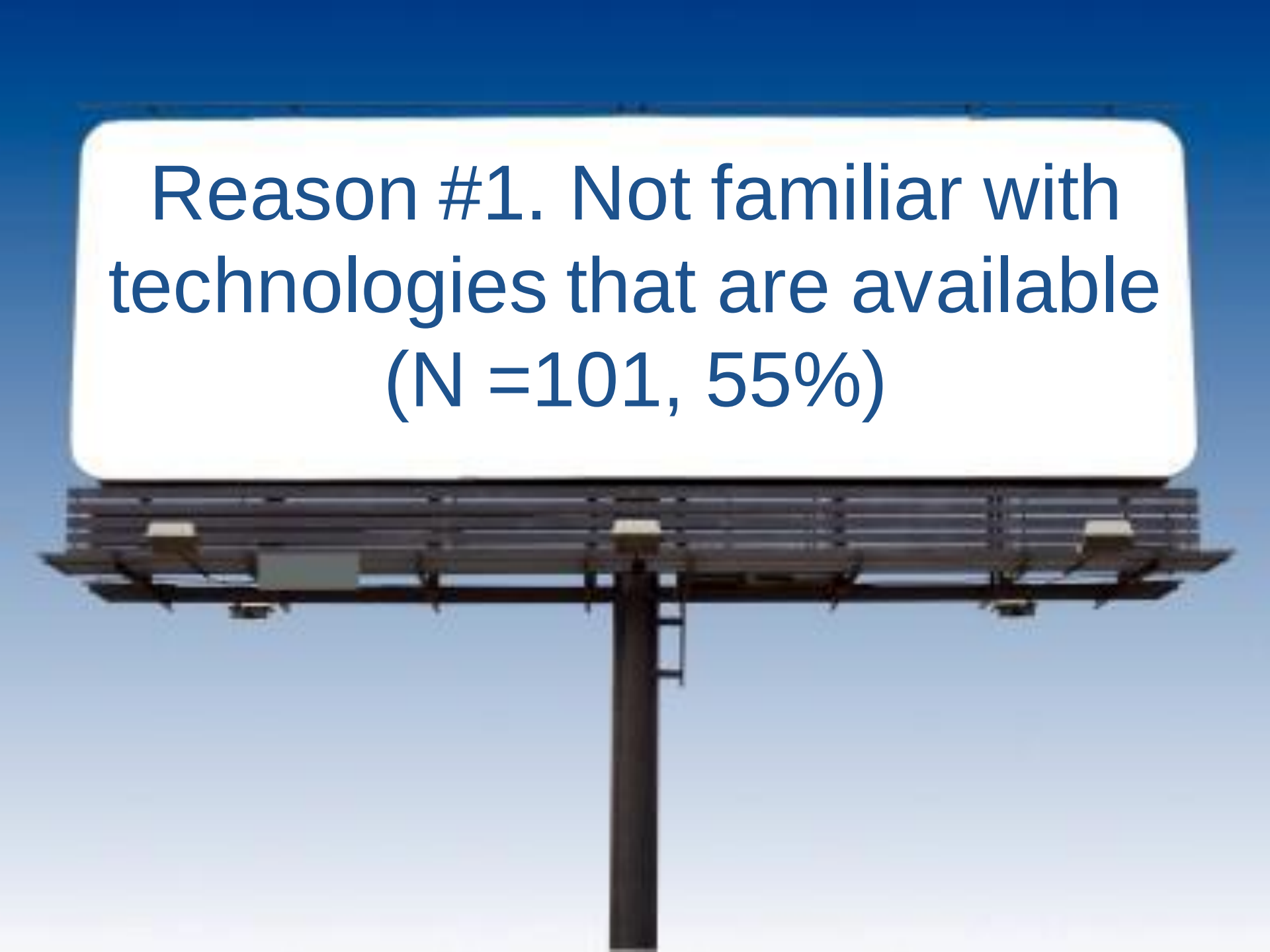
PURDUE
UNIVERSITY

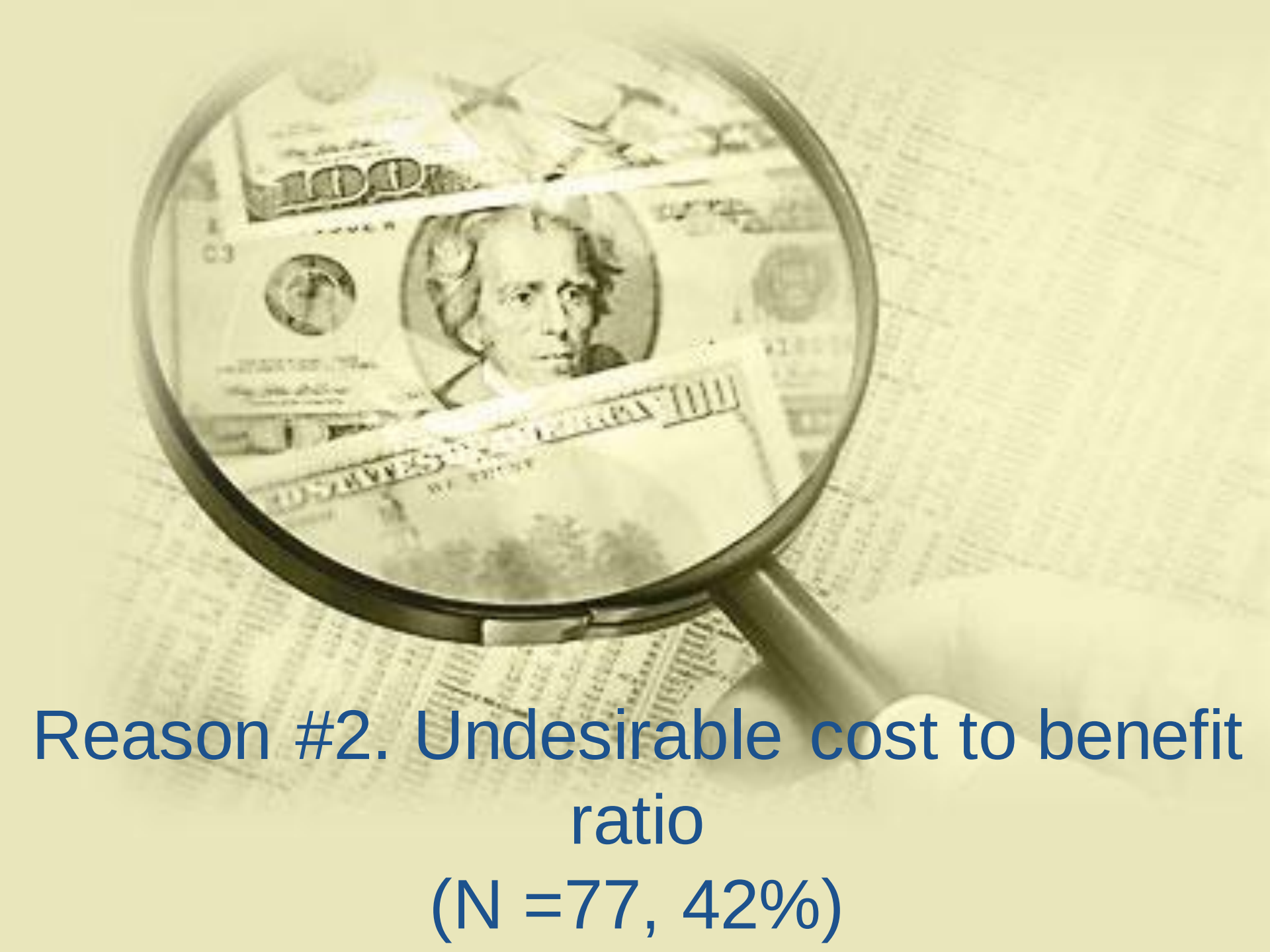
Did I get the wrong PhD?

The Book of David: Cow People Benefit Most



Why Have Adoption Rates Been Slow?

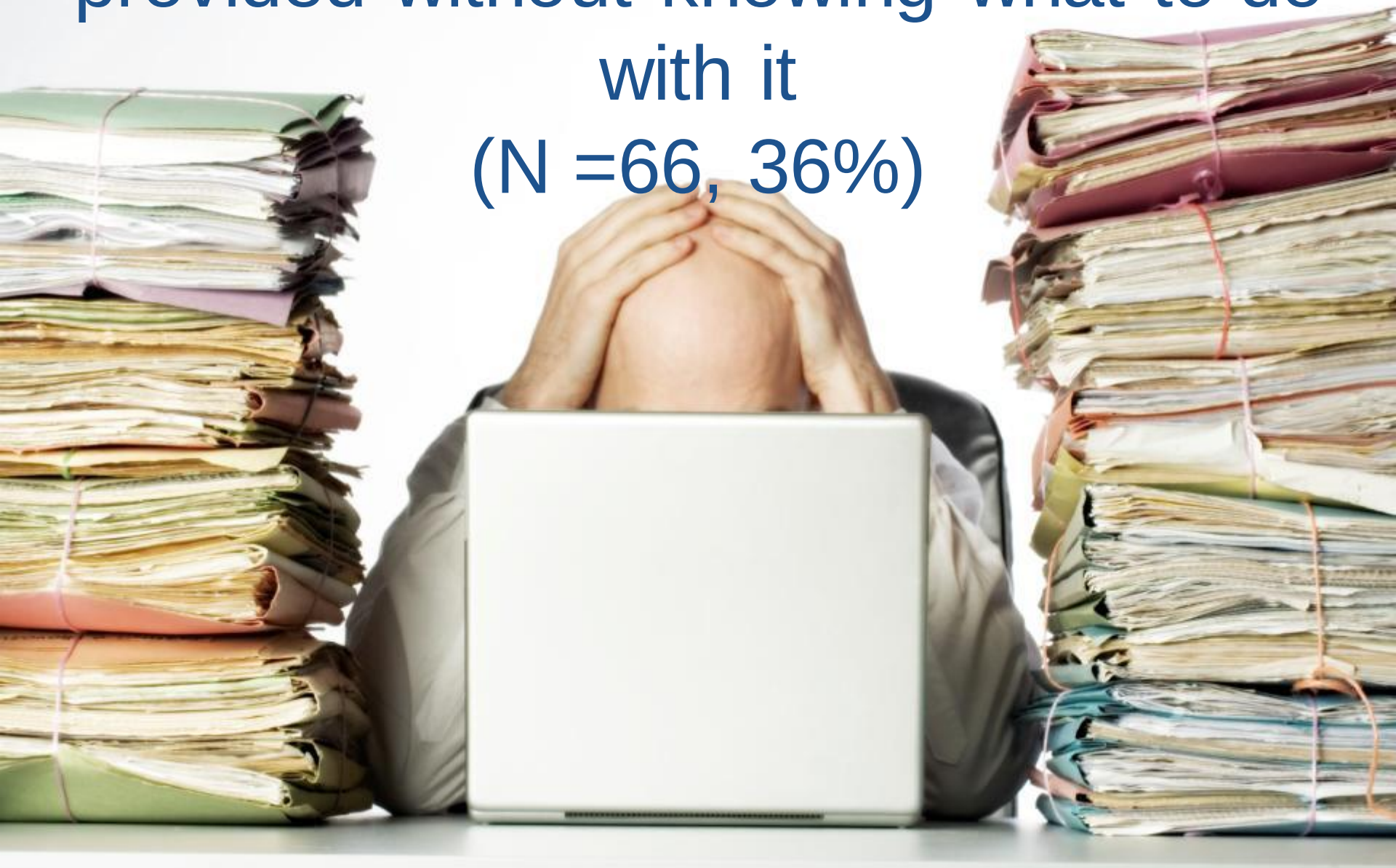

Reason #1. Not familiar with technologies that are available (N =101, 55%)



Reason #2. Undesirable cost to benefit ratio

(N =77, 42%)

Reason #3. Too much information provided without knowing what to do with it (N =66, 36%)



Reason #4. Not enough time to spend on technology (N =56, 30%)

Reason #5. Lack of perceived economic value (N =55, 30%)

Reason #6. Too Difficult or Complex to Use (N =53, 29%)

Reason #7. Poor technical support/training (N =52, 28%)

Reason #8. Better alternatives/easier to accomplish manually (N =43, 23%)

Reason #9. Failure in fitting with farmer patterns of work (N =40, 22%)

Reason #10. Fear of technology/computer illiteracy (N =39, 21%)

Reason #11. Not reliable or flexible enough (N =33, 18%)

Reason #99. Wrong College Degree (N =289, 100%)

Precision Dairy Technologies: A Producer Assessment

Matthew R. Borchers and Jeffrey M. Bewley
University of Kentucky
Department of Animal and Food Sciences

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UK Ag
DAIRY
UNIVERSITY OF
KENTUCKY®

Materials and Methods

- Statistical analyses performed
  - 152 returned surveys
  - 109 surveys used (72%)

- Statistical analyses
  - SAS® (v9.3) (Cary, NC)

Question 5. What automatic monitoring technologies do you currently have on your dairy? (If not applicable, select "Not applicable")

Most Used Parameters	Respondent Percentage
Daily milk yield	52.3%
Cow activity	41.3%
Not applicable[1]	31.2%
Mastitis	25.7%
Milk components (e.g. fat, protein, and SCC)	24.8%
Standing heat	21.1%
Feeding behavior	12.8%
Temperature	12.8%
Body weight	11.0%
Rumination	10.1%

[1]Respondents replying “Not applicable,” were those not currently utilizing precision technologies on their farms.

Question 5. What automatic monitoring technologies do you currently have on your dairy? (If not applicable, select "Not applicable")

Least Used Parameters	Respondent Percentage
Rumen activity	9.2%
Animal position and location	8.3%
Lying and standing behavior	8.3%
Jaw movement and chewing activity	7.3%
Hoof health	6.4%
Lameness	4.6%
Heart rate	3.7%
Body condition score	2.8%
Methane emissions	1.8%
Respiration rate	1.8%
Rumen pH	0.9%

Question 6. Rate the importance of the following criteria for evaluating technology purchases

Item	Mean ± SD
Benefit: cost ratio	4.57 ± 0.66
Total investment cost	4.28 ± 0.83
Simplicity and ease of use	4.26 ± 0.75
Proven performance through independent research	4.24 ± 0.75
Availability of local support	4.12 ± 0.95
Compatibility with existing dairy practices and systems	4.12 ± 0.86
Time involved using the technology	4.07 ± 0.88

[1]Results calculated by assigning the following values to response categories: Not important: 1, Of little importance: 2, Moderately important: 3, Important: 4, Very important: 5.

Question 7. Rate the potential usefulness of the following measures

Most Useful Parameters	Mean ± SD
Mastitis	4.77 ± 0.47
Standing heat	4.75 ± 0.55
Daily milk yield	4.72 ± 0.62
Cow activity	4.60 ± 0.83
Temperature	4.31 ± 1.04
Feeding behavior	4.30 ± 0.80
Milk components (e.g. fat, protein, and SCC)	4.28 ± 0.93
Lameness	4.25 ± 0.90
Rumination	4.08 ± 1.07
Hoof health	4.06 ± 0.89

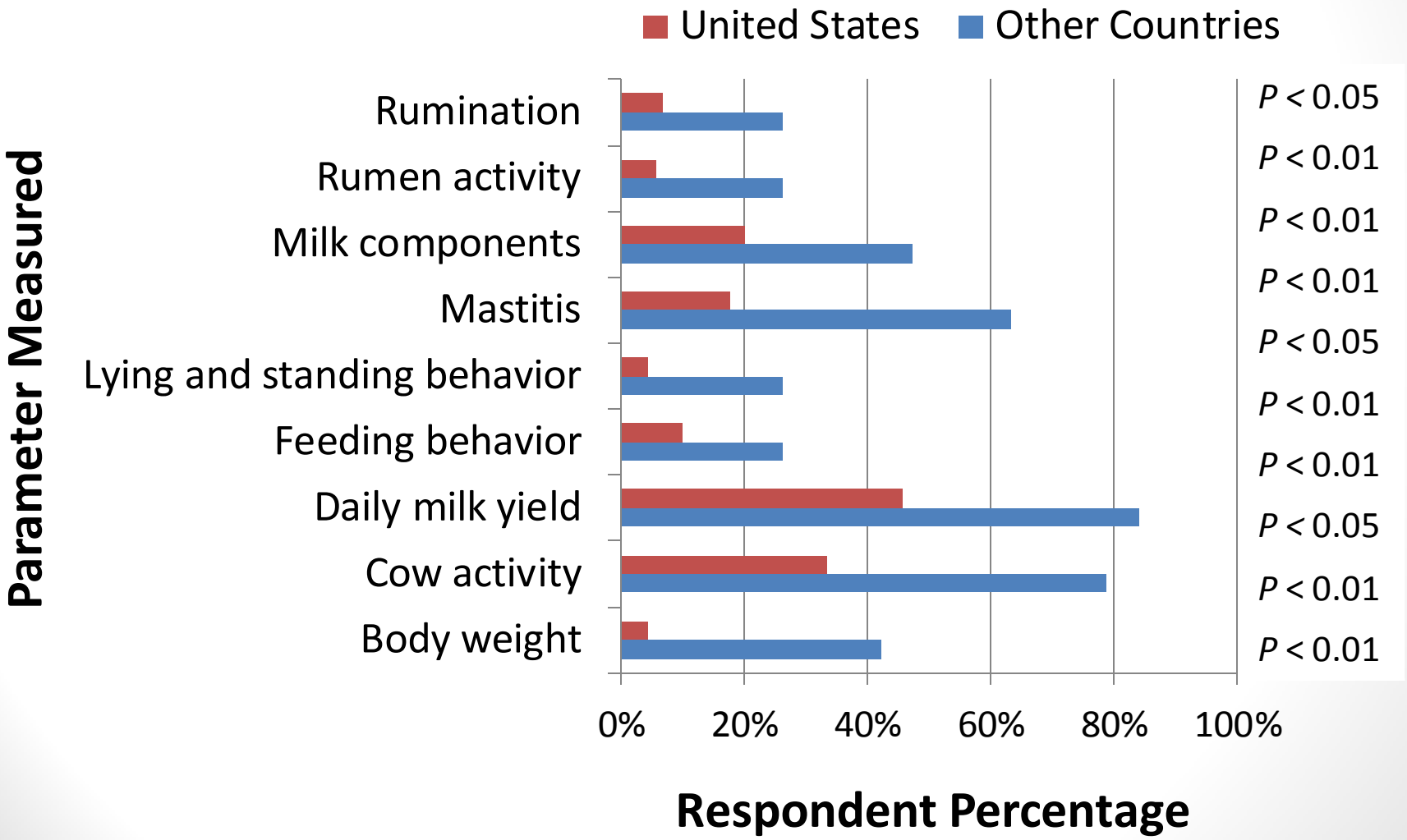
[1]Results calculated by assigning the following values to response categories: Not useful: 1, Of little usefulness: 2, Moderately useful: 3, Useful: 4, Very useful:5.

Question 7. Rate the potential usefulness of the following measures

Least Useful Parameters	Mean ± SD
Rumen activity	3.94 ± 1.10
Lying and standing behavior	3.79 ± 1.05
Rumen pH	3.62 ± 1.16
Jaw movement and chewing activity	3.61 ± 1.15
Respiration rate	3.40 ± 1.15
Body weight	3.26 ± 1.20
Body condition score	3.26 ± 1.15
Heart rate	3.07 ± 1.15
Animal position and location	2.75 ± 1.26
Methane emissions	2.20 ± 1.16

[1]Results calculated by assigning the following values to response categories: Not useful: 1, Of little usefulness: 2, Moderately useful: 3, Useful: 4, Very useful: 5.

Comparisons Between Countries for Parameters Currently Measured



Conclusions

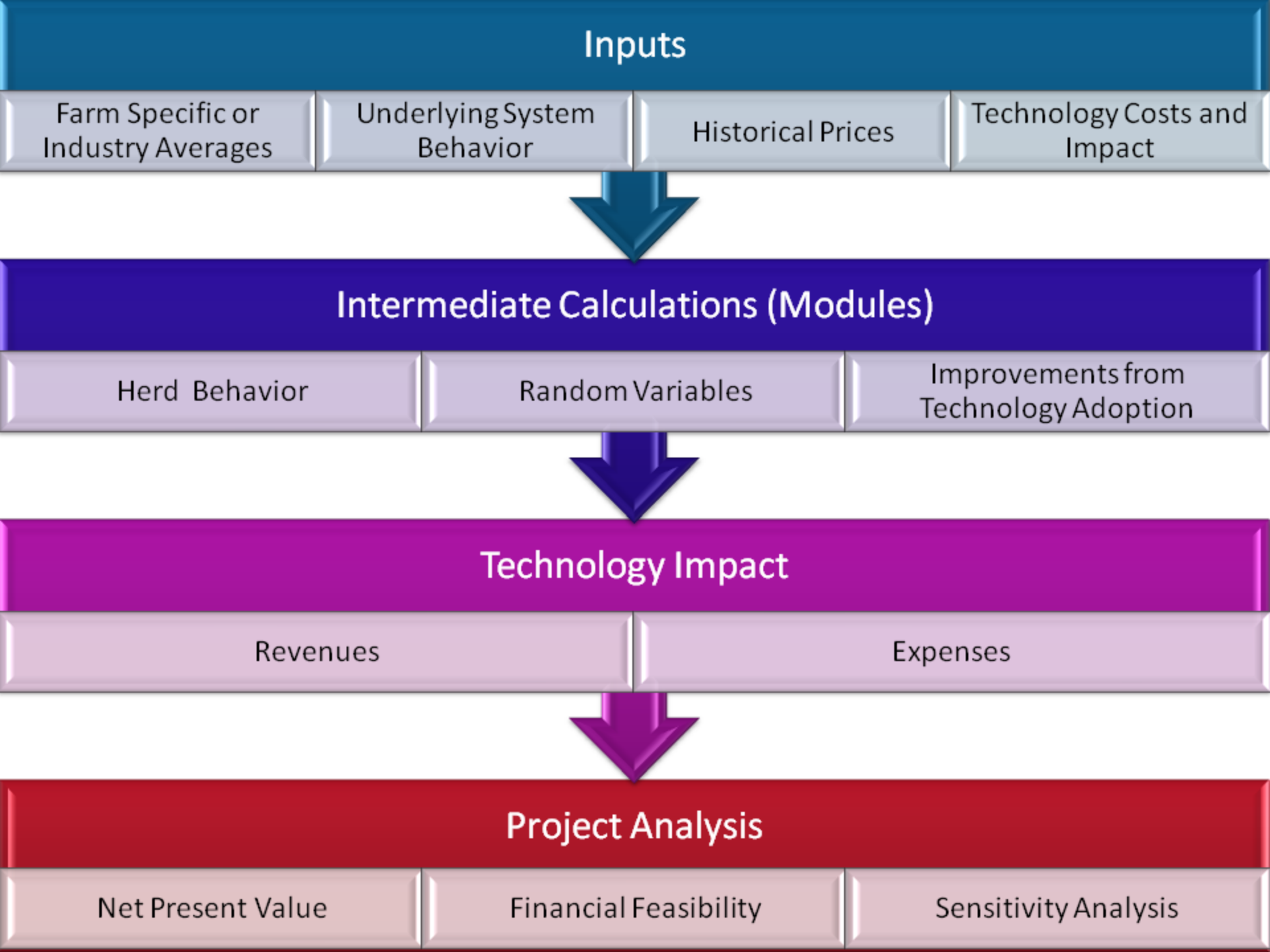
- Significant ($P < 0.05$) differences exist between the respondents from other countries and the United States, in the usage of various technologies
  - Indicative of a higher percentage of producers using technologies in other countries

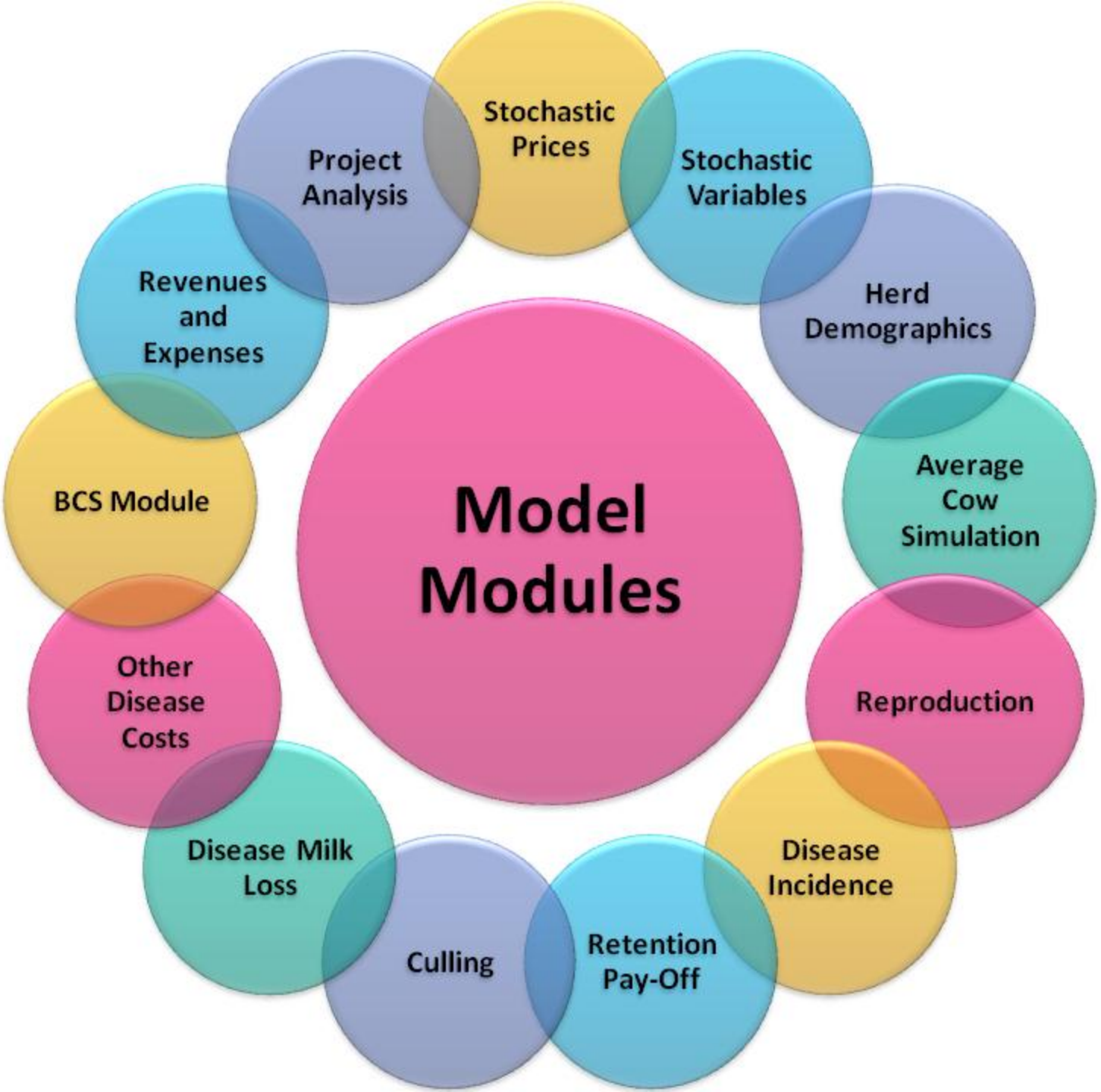
Economic Considerations

- Need to do investment analysis
- Not one size fits all
- Economic benefits observed quickest for heat detection/reproduction
- If you don't do anything with the information, it was useless
- Systems that measure multiple parameters make most sense
- Systems with low fixed costs work best for small farms

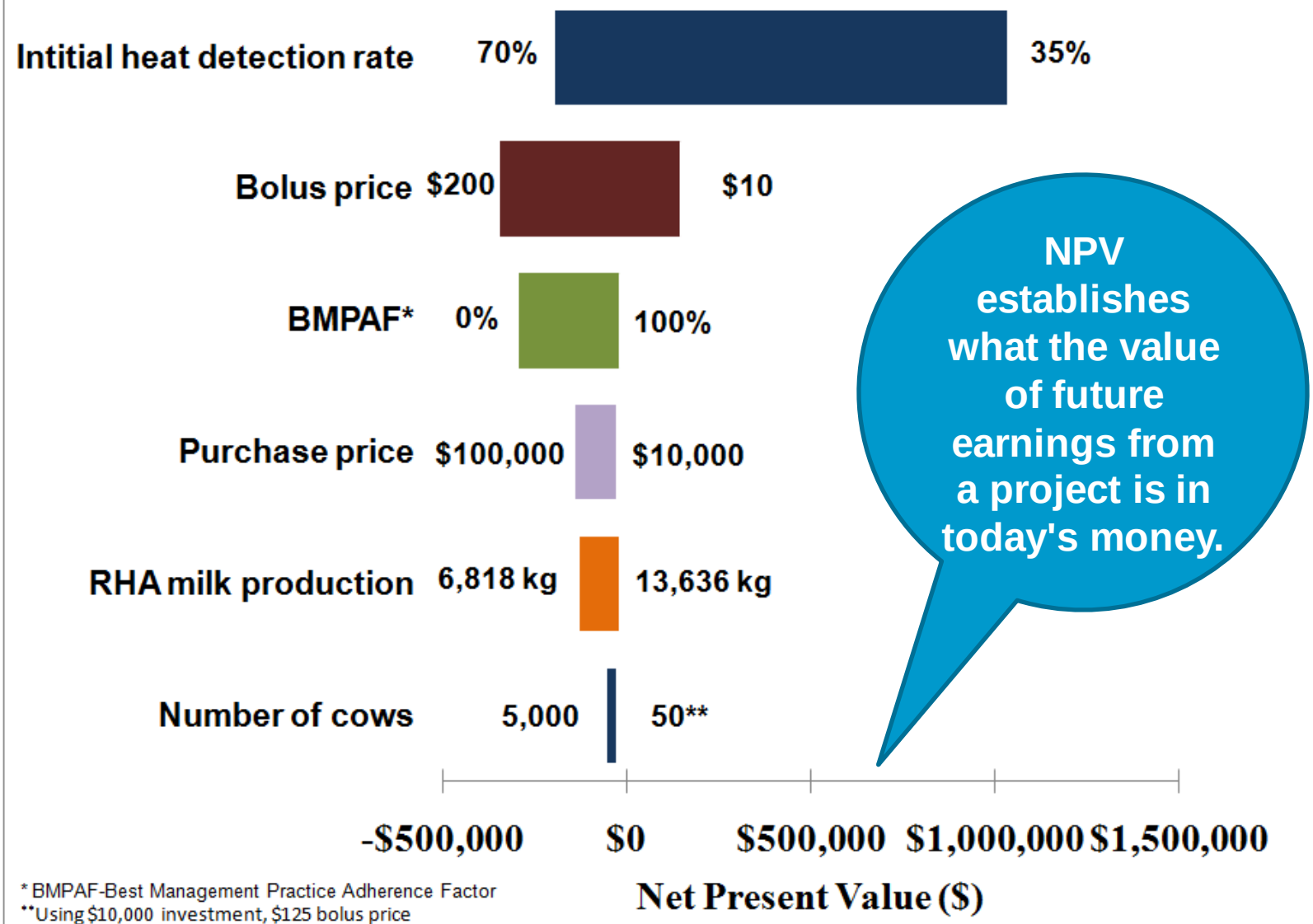
Purdue/Kentucky Investment Model

- Investment decisions for PDF technologies
- Flexible, partial-budget, farm-specific
- Simulates dairy for 10 years
- Includes hundreds of random values
- Measures benefits from improvements in productivity, animal health, and reproduction
- Models both biology and economics

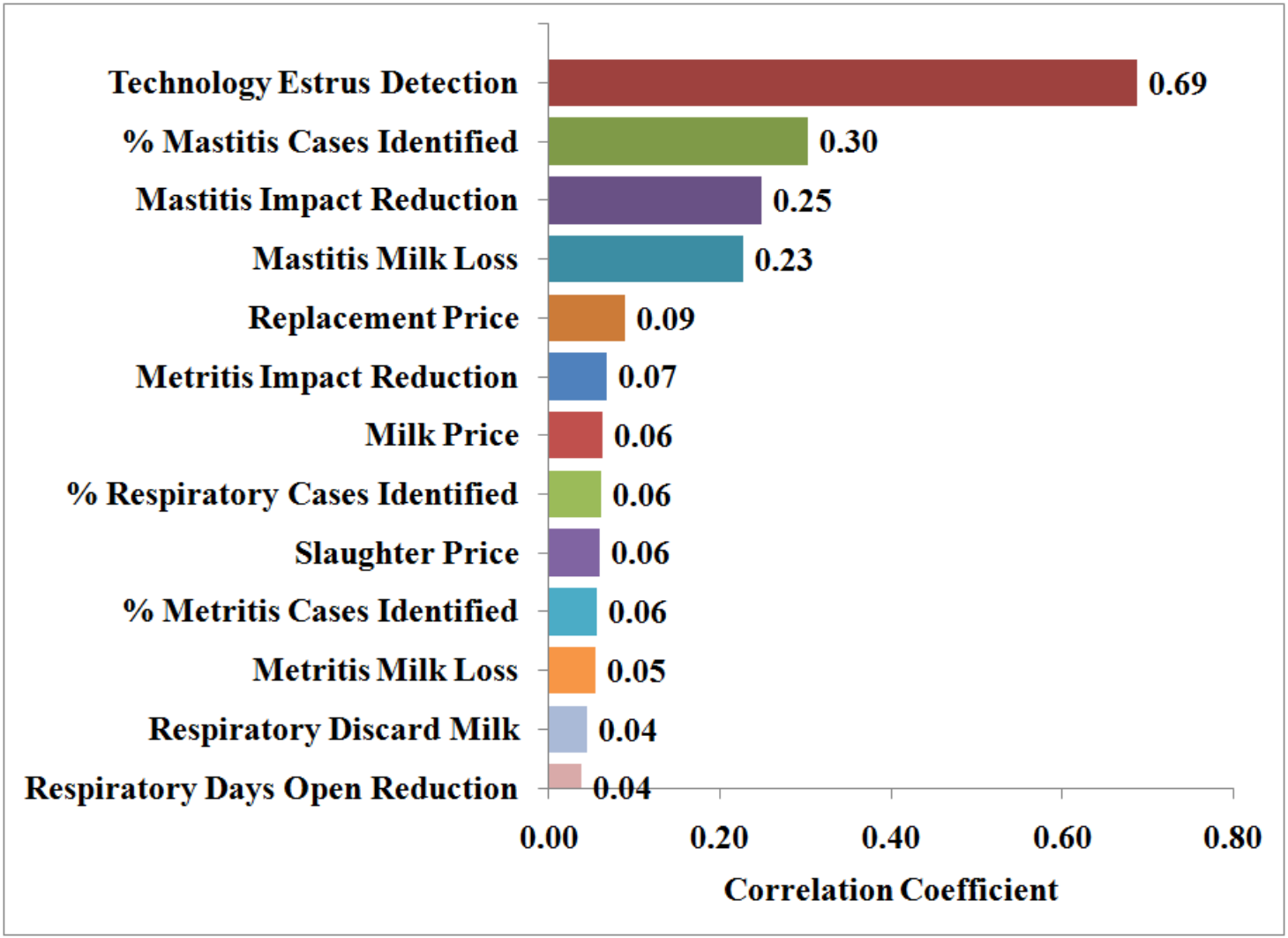

Inputs
Farm Specific or Industry Averages
Underlying System Behavior
Historical Prices
Technology Costs and Impact
Intermediate Calculations (Modules)
Herd Behavior
Random Variables
Improvements from Technology Adoption
Technology Impact
Revenues
Expenses
Project Analysis
Net Present Value
Financial Feasibility
Sensitivity Analysis


Model Modules
Stochastic Prices
Stochastic Variables
Herd Demographics
Average Cow Simulation
Reproduction
Disease Incidence
Retention Pay-Off
Culling
Disease Milk Loss
Other Disease Costs
BCS Module
Revenues and Expenses
Project Analysis

Tornado Diagram for Deterministic Factors Affecting NPV



Tornado Diagram for Stochastic Factors Affecting NPV



Sheldon's Friendship Flowchart
(as Modified by Wolowitz)

Place Phone Call

Home

No

Leave Message

Wait for Callback

Would You Like to Share a Meal

What Is the Response?

No

Yes

Dine Together?

Do You Enjoy a Hot Beverage?

What Is the Response?

No

Case:
Tea
Coffee
Cocoa

Have Tea
Have Coffee
Have Cocoa

n = No

Recreational Activities! Tell Me One of Your Interests?

No

ESC

Yes

LOA

n = 3

Do I Share That Interest?

Yes

Why Don't We Do That Together?

Partake in Interest

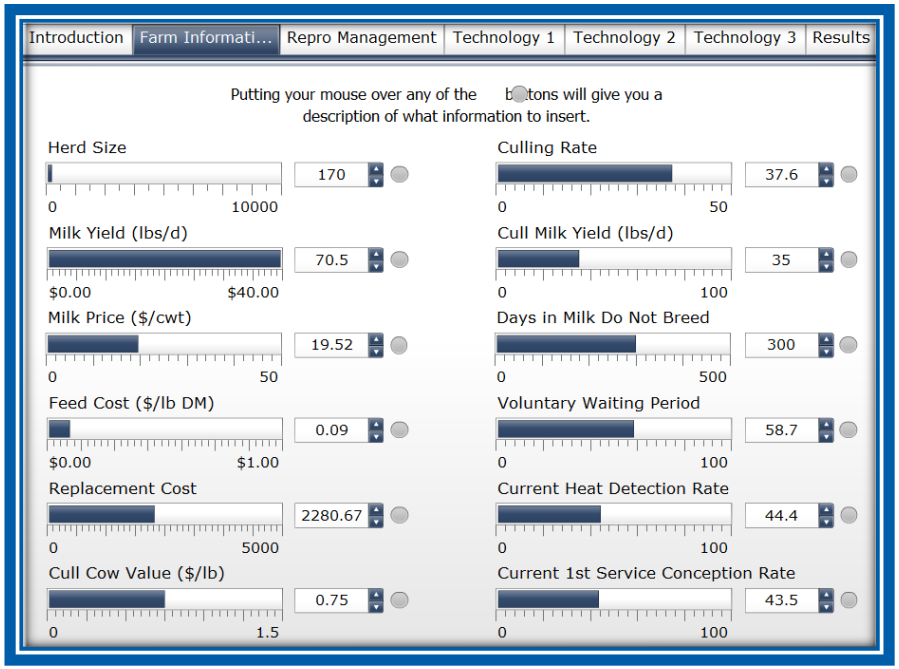
Begin Friendship

Investment Analysis of Automated Estrus Detection Technologies

K.A. Dolecheck, G. Heersche Jr., and J.M. Bewley
University of Kentucky

Objective

- Develop a decision-making tool
  - User-friendly
  - Farm-specific
  - Multiple technologies



- Dashboard tools provide interactive interfaces for analysis and decision support

Model Outputs

- Reproductive performance
  - Days open (French and Nebel, 2003)
- Investment analysis
  - Years to break even
  - Net present value

Calculations
Net Present Value

- Present value of cash inflows minus present value of cash outflows
- Accounts for timing of revenues and cash flows
- Good investment:
  Net present value ≥ 0
- System net present value determined by considering the value associated with a change in days open

Calculations
Other Considerations

- Accounts for costs associated with:
  - Pre-investment estrus detection method
  - Semen usage
  - Pregnancy diagnosis
- 10 year investment period

Limitations

- Investment analysis does not consider:
  - Additional benefits of technologies
  - Changes in heifer inventory
  - Effect on quality of producer's life

Tabs organize information

Introduction | Farm In[illegible]ati | Technology 2 | Technology 3 | Results

Investment Analysis of Heat Detection Technologies

Heat detection is a major concern on many dairies today.

, technologies used to monitor activity nd other cow parameters have been plied to manage heat detection.

Description and instructions for user

This net present value tool can be used to compare up to 3 different heat detection technologies in order to determine which might work best economically on a specific dairy.

To use, change herd and technology information in the input tabs and then review the outcome in the "Results" and "Before vs. After" tabs.

Developed by Karmella Dolecheck and Jeffrey Bewley
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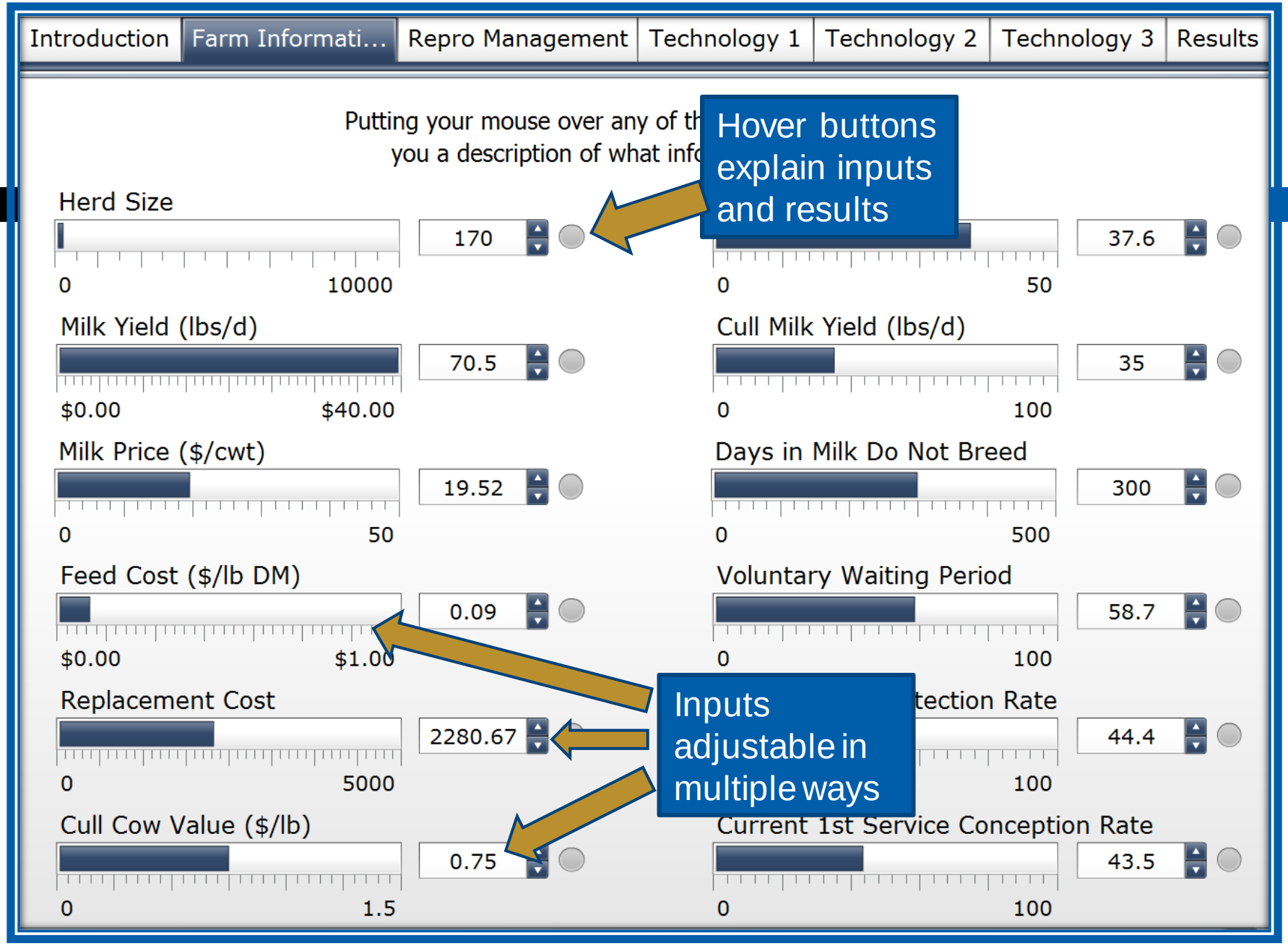
Dashboard available at: www2.ca.uky.edu/afsdairy/HeatDetectionTechnologies



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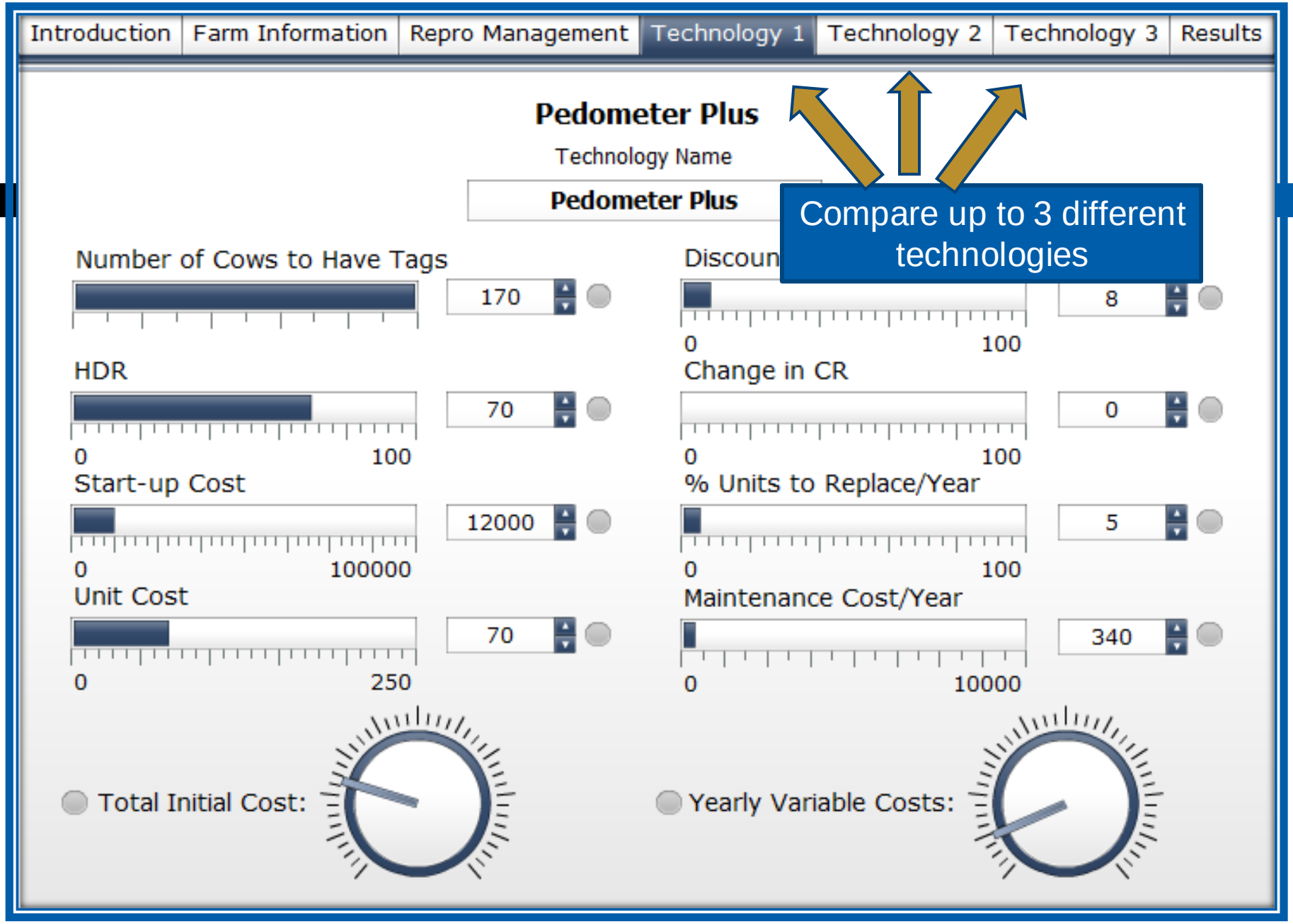
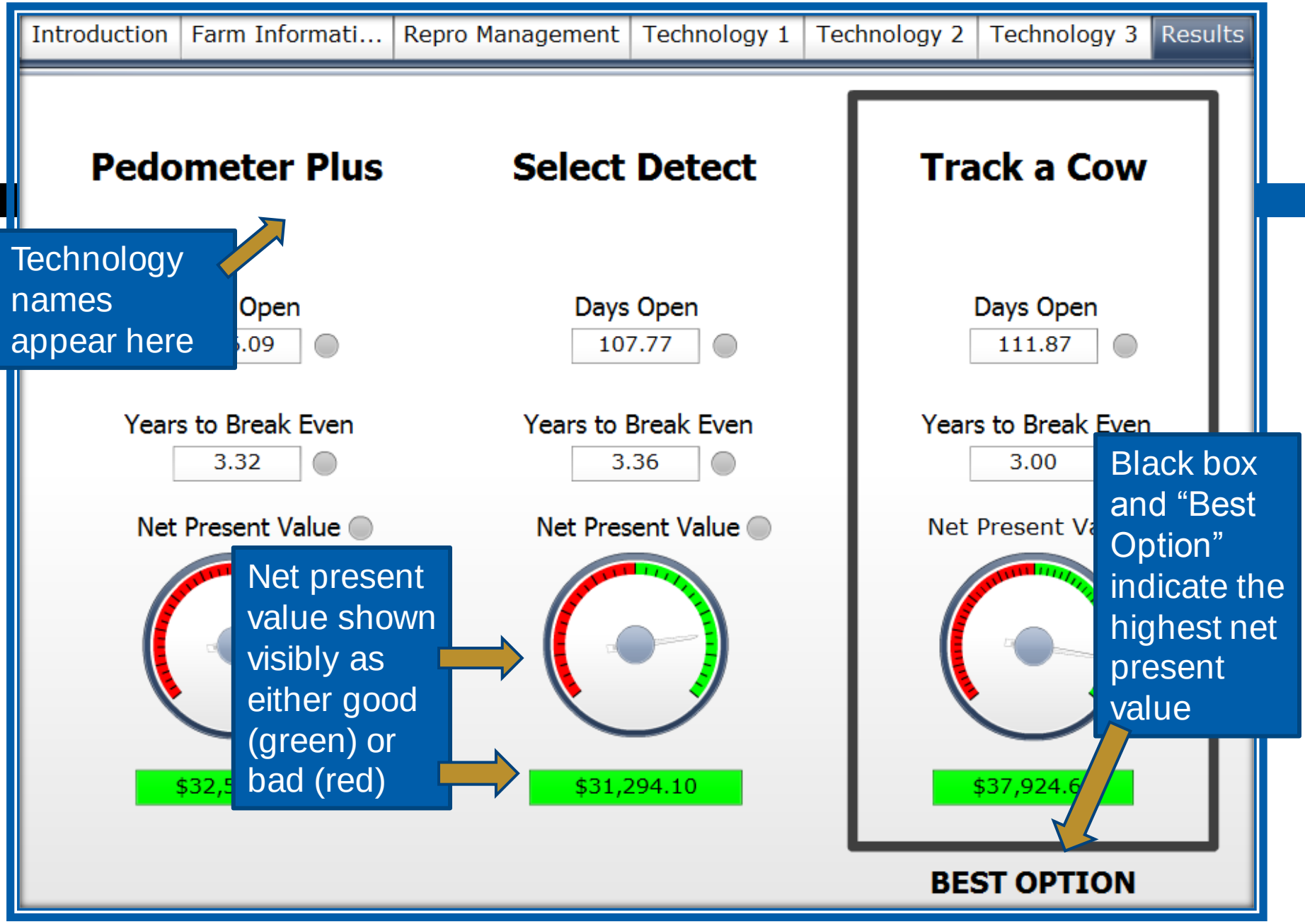


Dashboard available at: www2.ca.uky.edu/afsdairy/HeatDetectionTechnologies



Dashboard available at: www2.ca.uky.edu/afsdairy/HeatDetectionTechnologies

Farm Specific Inputs
Herd Assumptions

Input	Value	Source
Herd size	313	DairyMetrics, July 2013
Milk price	$0.43/kg	FAPRI, 2013
Milk yield	33.7 kg/cow/d	DairyMetrics, July 2013
Feed cost	$0.20/kg DM	FAPRI, 2013

Farm Specific Inputs
Culling & Replacement Assumptions

Input	Value	Source
Culling rate	38.1%	DairyMetrics, July 2013
Days in milk do not breed	300 d	Model assumption
Cull milk yield	15.88 kg/d	Model assumption
Replacement cost	$1785	Liang, 2013
Cull cow value	$1.67/kg	FAPRI, 2013

Farm Specific Inputs
Reproduction Assumptions

Input	Value	Source
Voluntary waiting period	58.4 d	DairyMetrics, July 2013
Current estrus detection rate	49.4%	DairyMetrics, July 2013
Current 1st service conception rate	37.8%	DairyMetrics, July 2013

Farm Specific Inputs
Reproduction Assumptions

Input	Value	Source
Cost of 1st service semen	$15	Model assumption
Cost of ≥ 2nd service semen	$10	Model assumption
Cost of pregnancy detection	$3/head	Galvao et al., 2013
Pre-investment estrus detection method	Visual	Model assumption

Technology Inputs

- Initial investment
  - $5,000 (Low)
  - $10,000 (High)
- Unit price
  - $50 (50)
  - $100 (100)
- Estrus detection rate
  - 70% (70)
  - 90% (90)

System Inputs
Initial Costs

System	Start-Up Cost	Unit Cost	Total Initial Investment
Low-50	$5,000	$50	$13,465
Low-100	$5,000	$100	$21,930
High-50	$10,000	$50	$18,465
High-100	$10,000	$100	$26,930

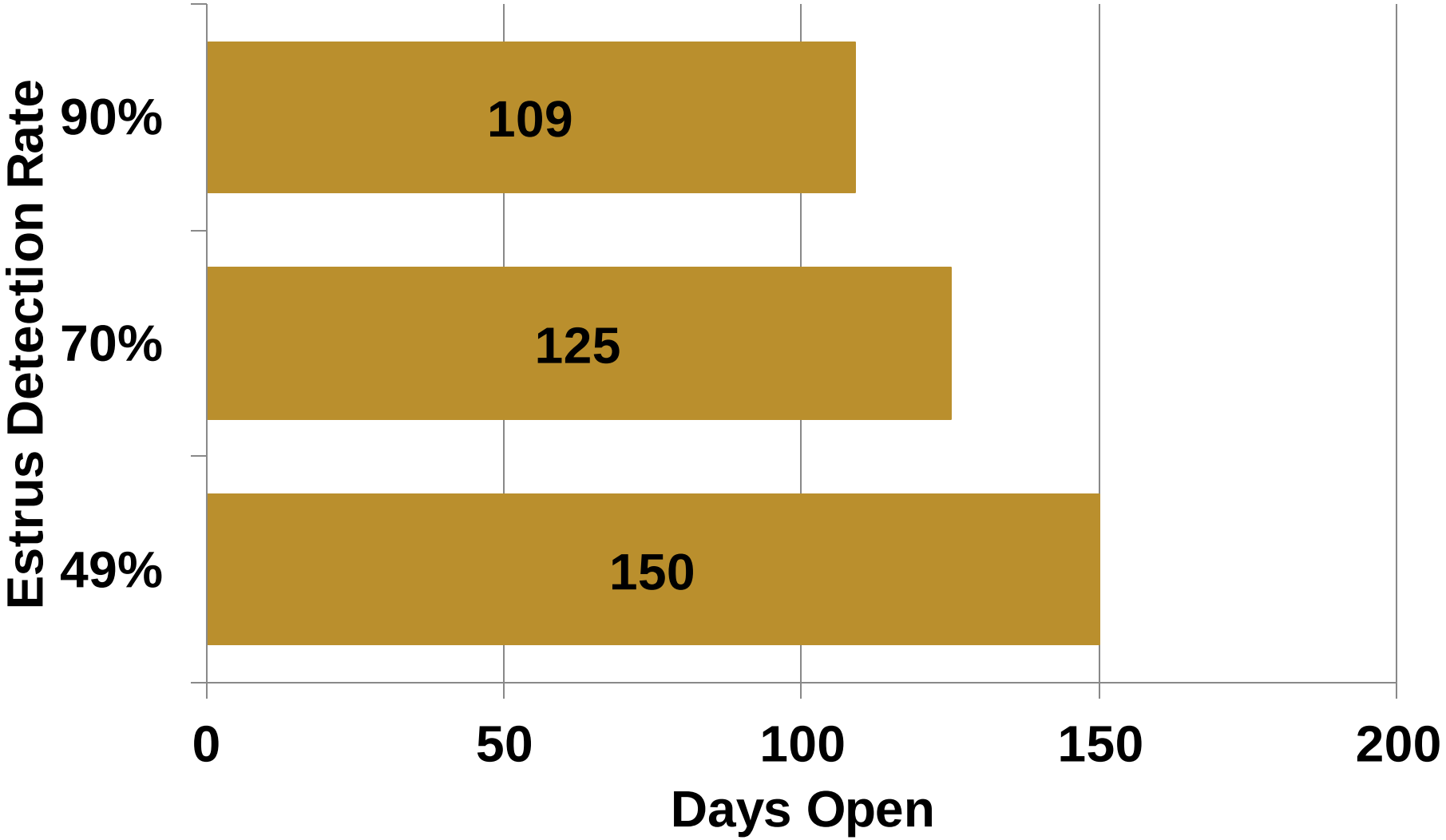
Low: $5,000 initial investment
High: $10,000 initial investment
50: $50 unit price
100: $100 unit price

Other Assumptions

- Discount rate = 8.0% (Bewley et al., 2010)
- Every animal requires a unit
- Replace 5% of units each year

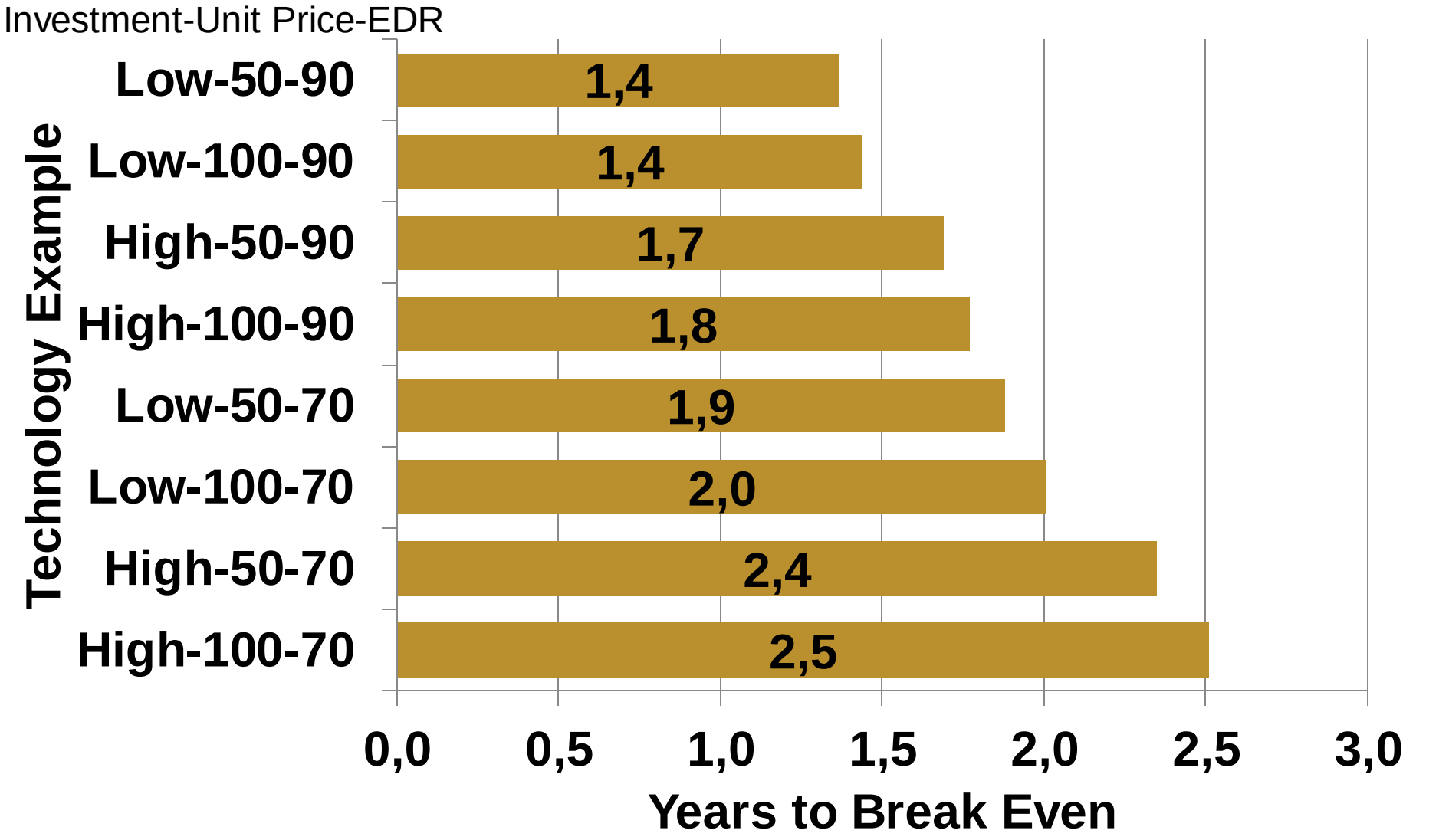
Analysis Results

Days Open



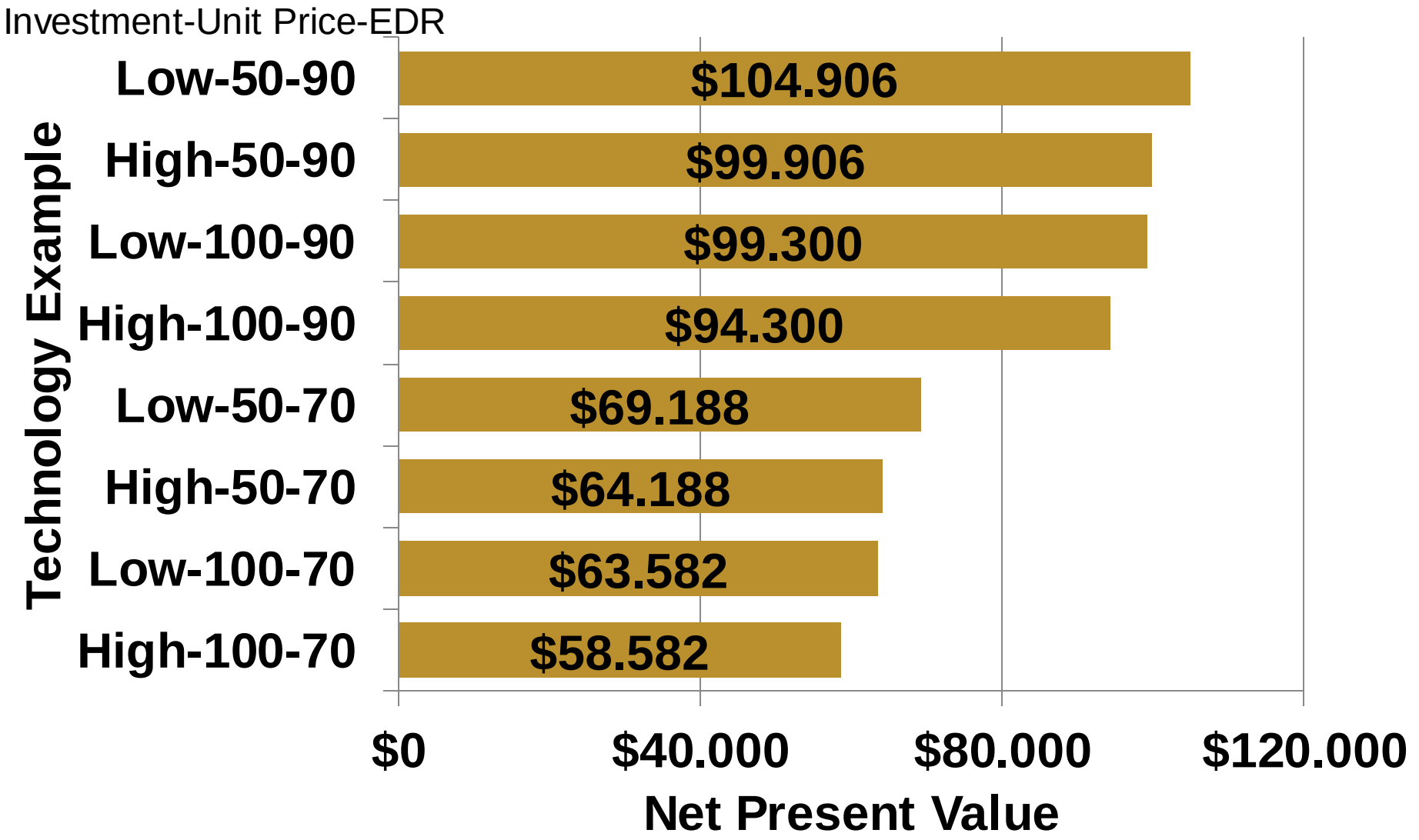
Analysis Results
Years to Break Even

Low: $5,000 initial investment
High: $10,000 initial investment
50: $50 unit price
100: $100 unit price
70: 70% estrus detection rate
90: 90% estrus detection rate



Analysis Results
Net Present Value

Low: $5,000 initial investment
High: $10,000 initial investment
50: $50 unit price
100: $100 unit price
70: 70% estrus detection rate
90: 90% estrus detection rate



Conclusions

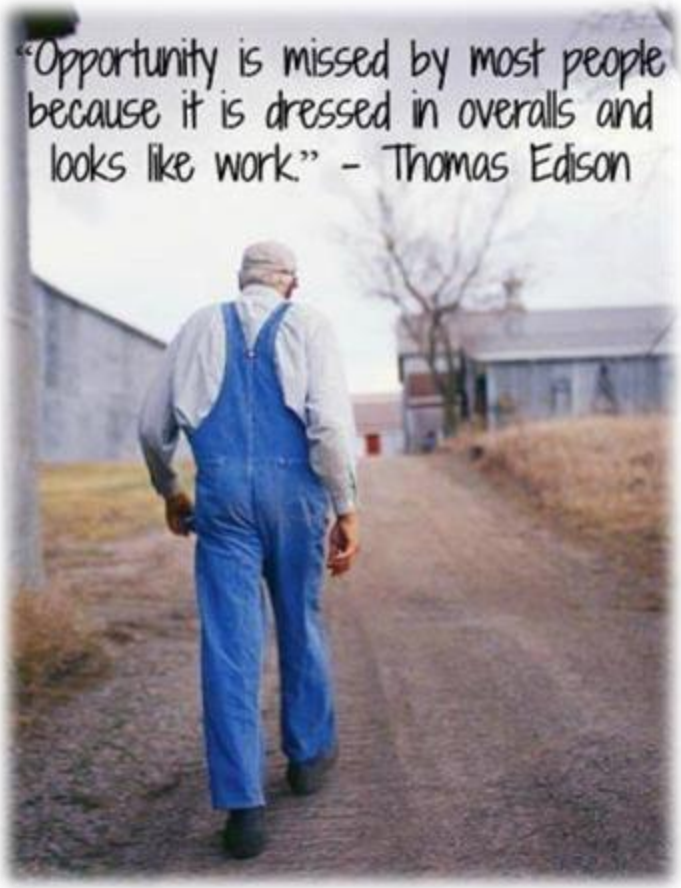
- Change in days open is affected by estrus detection rate
- Years to break even is affected by:
  - 1) Estrus detection rate
  - 2) Initial investment cost
  - 3) Cow unit cost
- Net present value is affected by:
  - 1) Estrus detection rate
  - 2) Cow unit cost
  - 3) Initial investment cost

Conclusions

- Starting point determines investment profitability
- Accurate information is essential for accurate results
  - Producer
  - Technology manufacturers
- Dairy producers considering purchasing an automated estrus detection technology system can use this model as a decision support tool

Cautious Optimism

- Critics say it is too technical or challenging
- We are just beginning
- Precision Dairy won't change cows or people
- Will change how they work together
- Improve farmer and cow well-being



Path to Success

- Continue this rapid innovation
- Maintain realistic expectations
- Respond to farmer questions and feedback
- Never lose sight of the cow
- Educate, communicate, and collaborate

Future Vision

- New era in dairy management
- Exciting technologies
- New ways of monitoring and improving animal health, well-being, and reproduction
- Analytics as competitive advantage
- Economics and human factors are key

Questions?

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