Economic Model of the Costs of Emptying On-site Sanitation Facilities: from Emptying to Resource Recovery or Disposal

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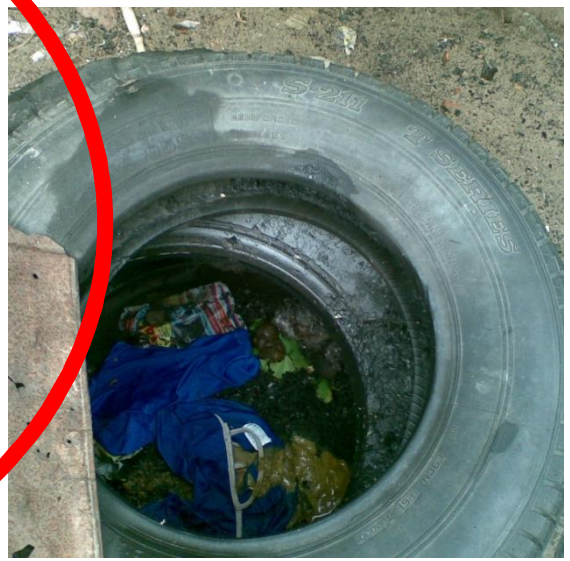
Economic impacts

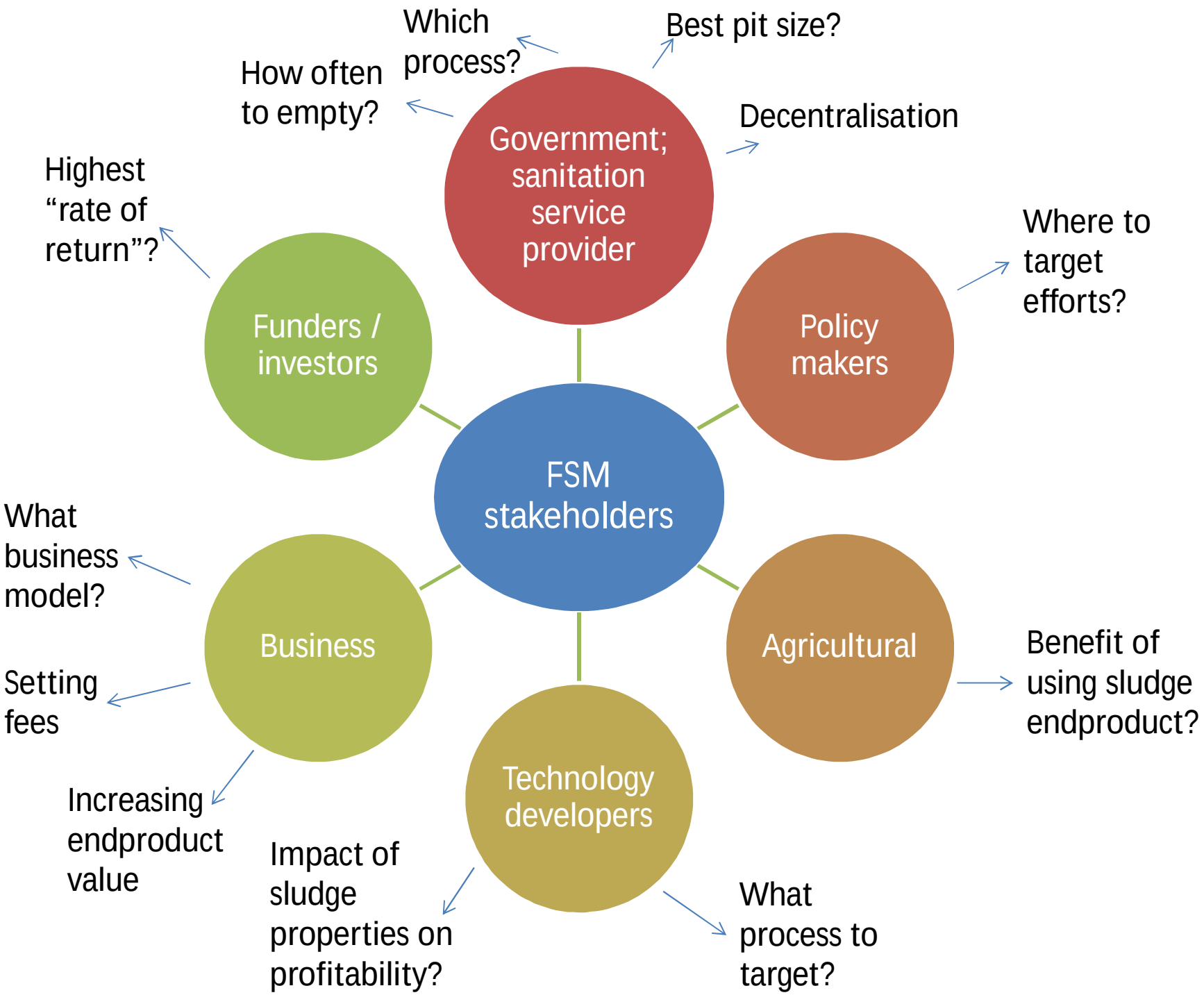
Health impacts

Environmental impacts

Poor sanitation & hygiene

Many inter-dependent factors
- Environmental
- Human
- Policy
- Financial
- ....etc




FSM stakeholders
Government; sanitation service provider
Which process?
Best pit size?
How often to empty?
Decentralisation
Funders / investors
Highest "rate of return"?
Policy makers
Where to target efforts?
Business
What business model?
Setting fees
Increasing endproduct value
Agricultural
Benefit of using sludge endproduct?
Technology developers
Impact of sludge properties on profitability?
What process to target?

Modelling sludge quantity & characteristics, costs & revenues through the FSM system

Emptying

Conveyance

Treatment

Reuse / end disposal

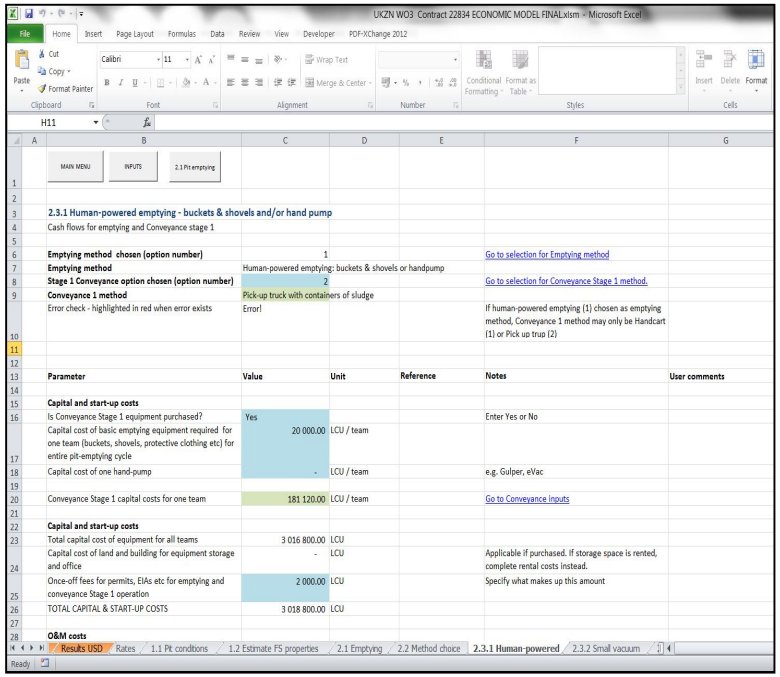
Changing sludge quantity

Changing sludge characteristics (solids, nutrients, calorific value, pathogens)

Changing costs & revenues

Scope of model

- Excel spreadsheet
- On-site sanitation
  - Pits
  - Septic tanks
  - Urine diversion
- Sludge removed off-site
- Multiple options for each stage of FSM chain
- Outputs
  - Financial
  - Non-financial



UKZN WO3 Contract 22834 ECONOMIC MODEL FINAL.xlsm - Microsoft Excel

MAIN MENU | INPUTS | 2.1 Pit emptying

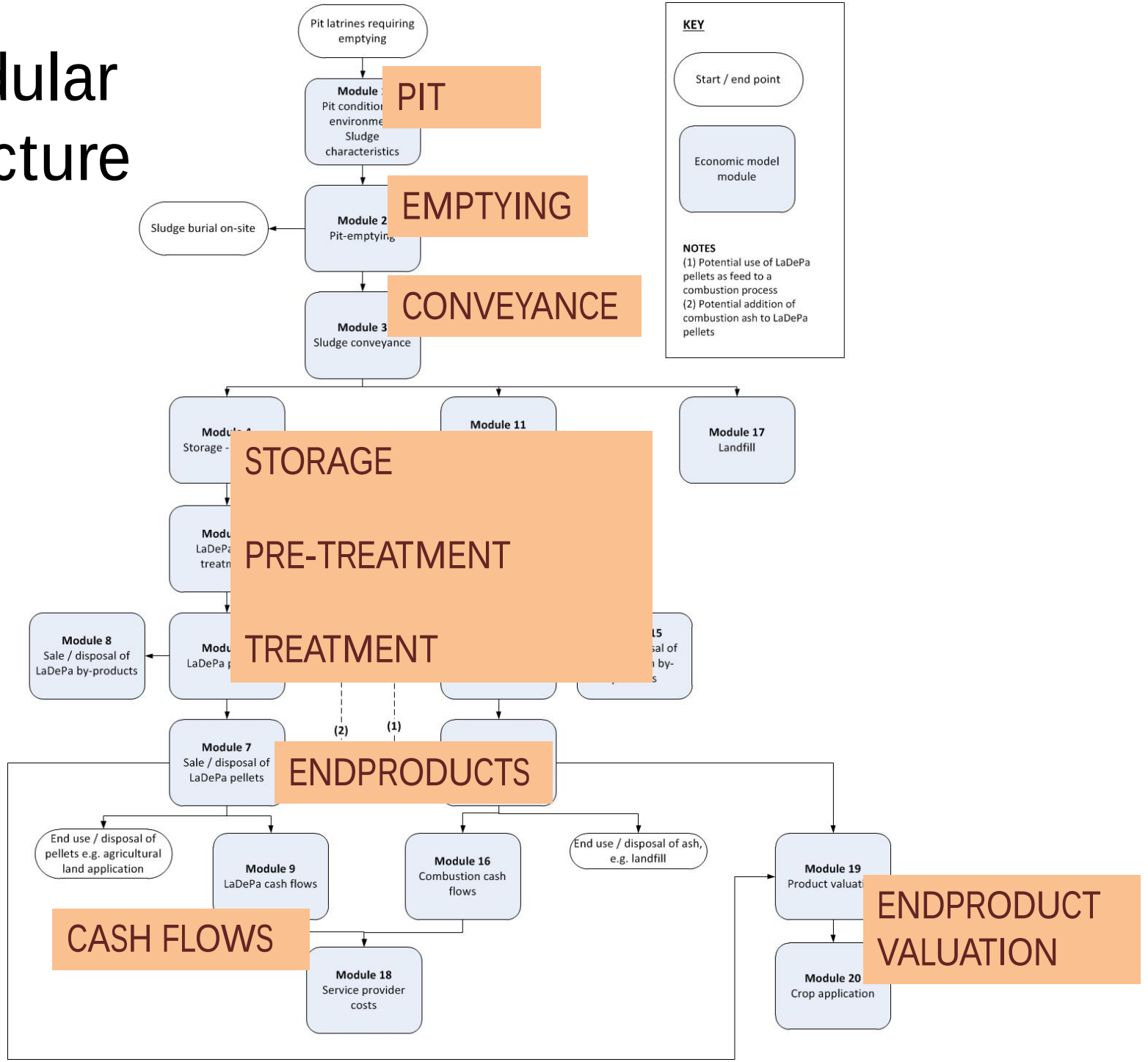
2.3.1 Human-powered emptying - buckets & shovels and/or hand pump

Cash flows for emptying and Conveyance stage 1

Emptying method chosen (option number)	1			Go to selection for Emptying method	
Emptying method	Human-powered emptying: buckets & shovels or handpump				
Stage 1 Conveyance option chosen (option number)	2			Go to selection for Conveyance Stage 1 method.	
Conveyance 1 method	Pick-up truck with containers of sludge				
Error check - highlighted in red when error exists	Error!			If human-powered emptying (1) chosen as emptying method, Conveyance 1 method may only be Handcart (1) or Pick up trup (2)	
Parameter	**Value**	**Unit**	**Reference**	**Notes**	**User comments**
Capital and start-up costs					
Is Conveyance Stage 1 equipment purchased?	Yes			Enter Yes or No	
Capital cost of basic emptying equipment required for one team (buckets, shovels, protective clothing etc) for entire pit-emptying cycle	20 000.00	LCU / team			
Capital cost of one hand-pump	-	LCU / team		e.g. Gulper, eVac	
Conveyance Stage 1 capital costs for one team	181 120.00	LCU / team		Go to Conveyance Inputs	
Capital and start-up costs					
Total capital cost of equipment for all teams	3 016 800.00	LCU			
Capital cost of land and building for equipment storage and office	-	LCU		Applicable if purchased. If storage space is rented, complete rental costs instead.	
Once-off fees for permits, EIAs etc for emptying and conveyance Stage 1 operation	2 000.00	LCU		Specify what makes up this amount	
TOTAL CAPITAL & START-UP COSTS	3 018 800.00	LCU			
O&M costs					

Results USD | Rates | 1.1 Pit conditions | 1.2 Estimate FS properties | 2.1 Emptying | 2.2 Method choice | 2.3.1 Human-powered | 2.3.2 Small vacuum

Modular structure



4 emptying options

Human-powered: manual

Human powered: improved manual – e.g. Gulper, eVac

Small vacuum tanker

Large vacuum tanker

7 conveyance options & combinations of these

Container on handcart

Pick up truck with containers

Small vacuum tanker

Large vacuum tanker

Intermediate storage tank

Transfer station – liquid connection to sewer

Sewer discharge station

Example combination:

Treatment

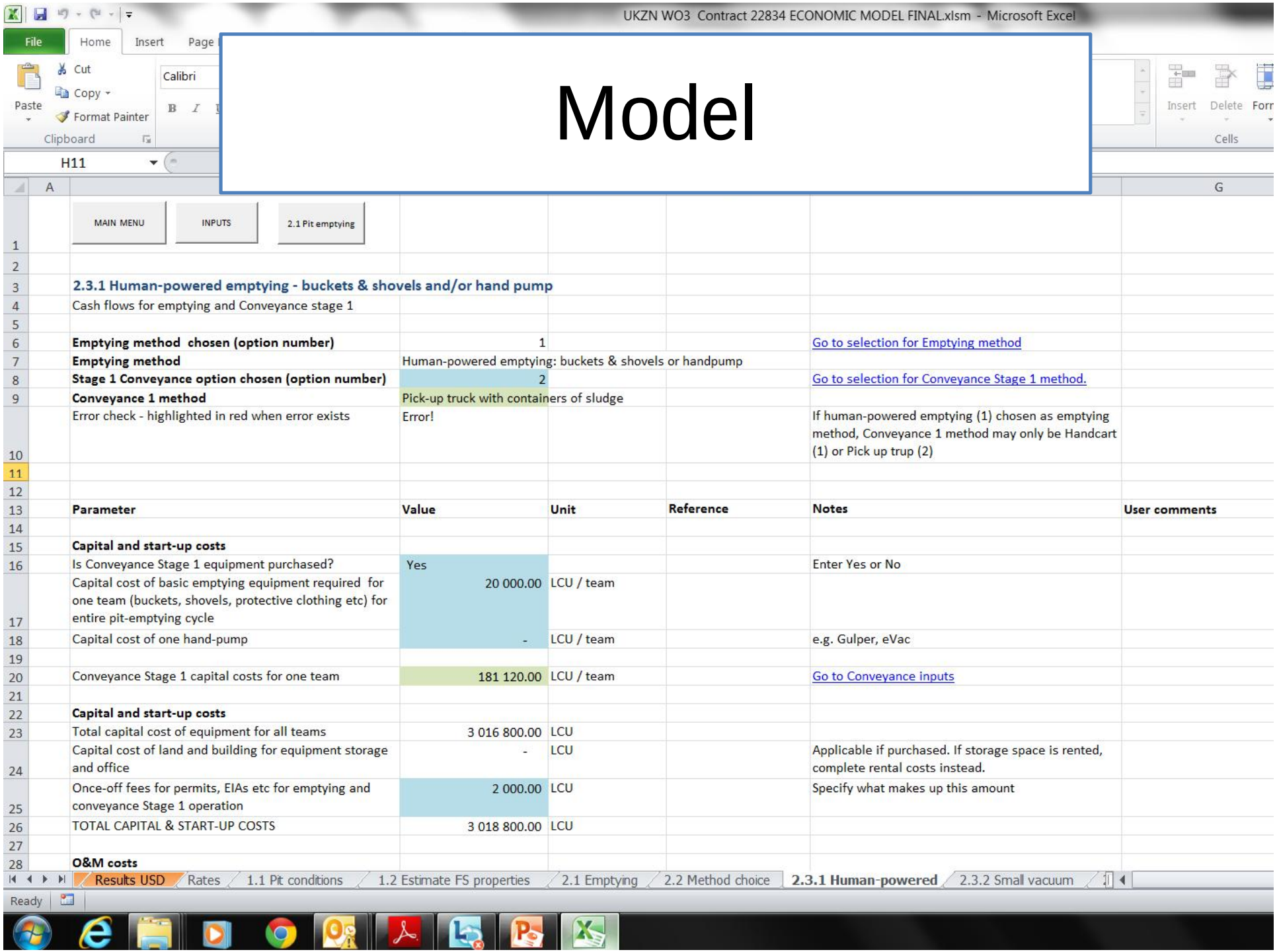
LaDePa (Latrine Dehydration Pasteurisation)

PELLET PRODUCT

Combustion

ASH PRODUCT

Landfill (‘do nothing’ option)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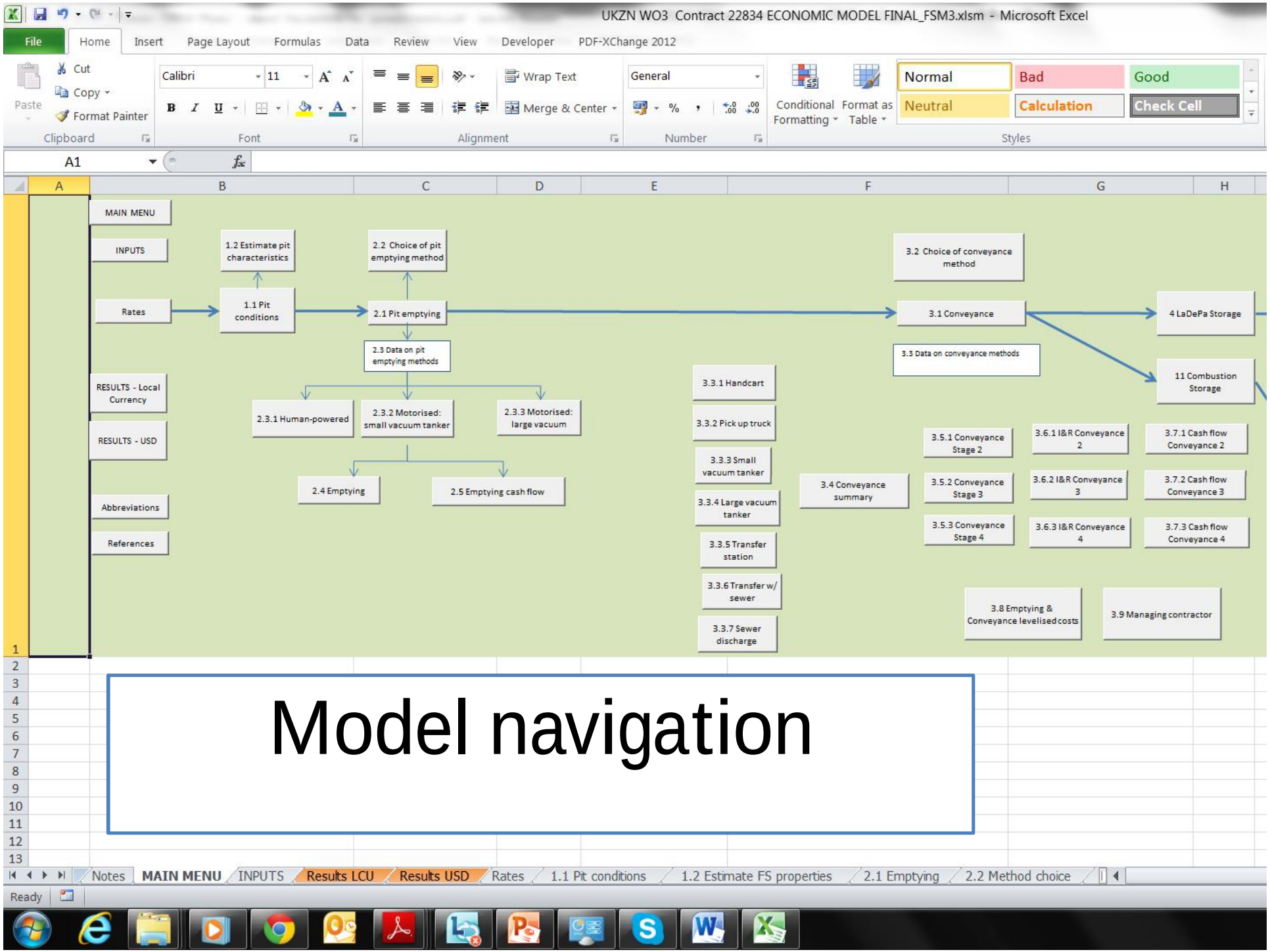
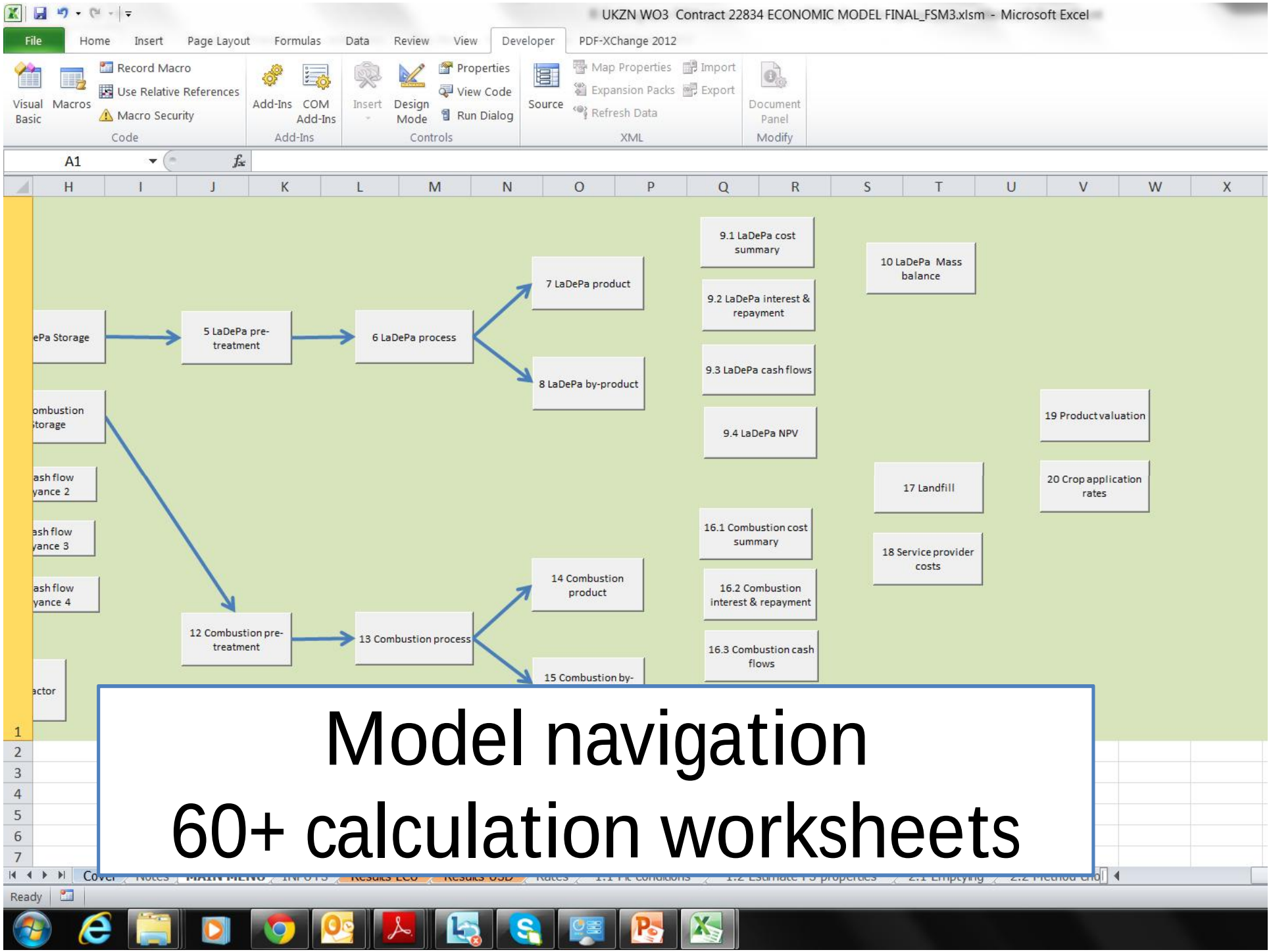
Model
MAIN MENU
INPUTS
2.1 Pit emptying
2.3.1 Human-powered emptying - buckets & shovels and/or hand pump
Cash flows for emptying and Conveyance stage 1
Emptying method chosen (option number) 1 Go to selection for Emptying method
Emptying method Human-powered emptying: buckets & shovels or handpump
Stage 1 Conveyance option chosen (option number) 2 Go to selection for Conveyance Stage 1 method.
Conveyance 1 method Pick-up truck with containers of sludge
Error check - highlighted in red when error exists Error!
If human-powered emptying (1) chosen as emptying method, Conveyance 1 method may only be Handcart (1) or Pick up trup (2)
Parameter | Value | Unit | Reference | Notes | User comments
Capital and start-up costs
Is Conveyance Stage 1 equipment purchased? Yes Enter Yes or No
Capital cost of basic emptying equipment required for one team (buckets, shovels, protective clothing etc) for entire pit-emptying cycle 20 000.00 LCU / team
Capital cost of one hand-pump - LCU / team e.g. Gulper, eVac
Conveyance Stage 1 capital costs for one team 181 120.00 LCU / team Go to Conveyance inputs
Capital and start-up costs
Total capital cost of equipment for all teams 3 016 800.00 LCU
Capital cost of land and building for equipment storage and office - LCU Applicable if purchased. If storage space is rented, complete rental costs instead.
Once-off fees for permits, EIAs etc for emptying and conveyance Stage 1 operation 2 000.00 LCU Specify what makes up this amount
TOTAL CAPITAL & START-UP COSTS 3 018 800.00 LCU
O&M costs
Results USD
Rates
1.1 Pit conditions
1.2 Estimate FS properties
2.1 Emptying
2.2 Method choice
2.3.1 Human-powered
2.3.2 Small vacuum
Ready

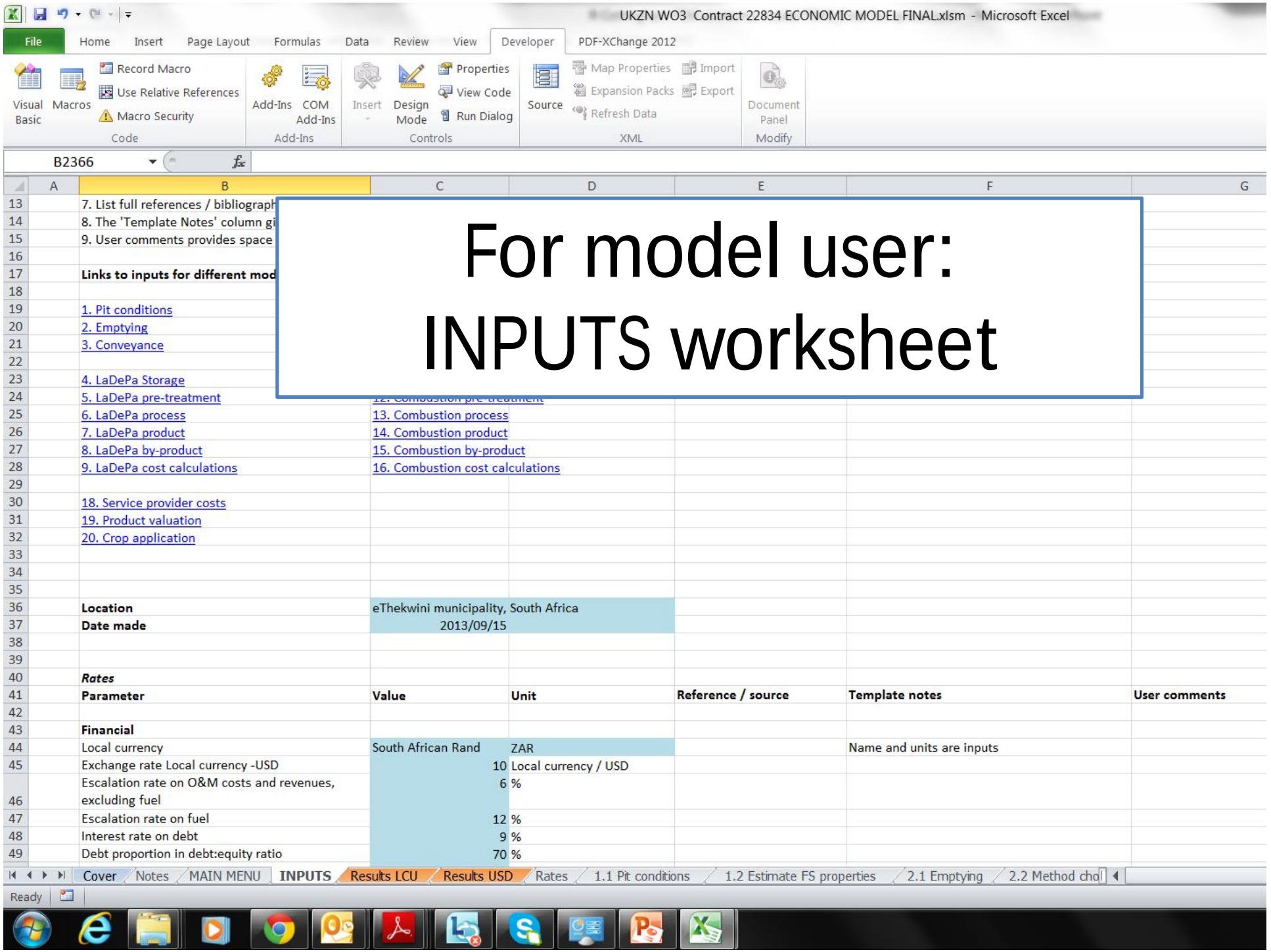


Model navigation



Model navigation

60+ calculation worksheets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Controls
Source
Map Properties
Expansion Packs
Refresh Data
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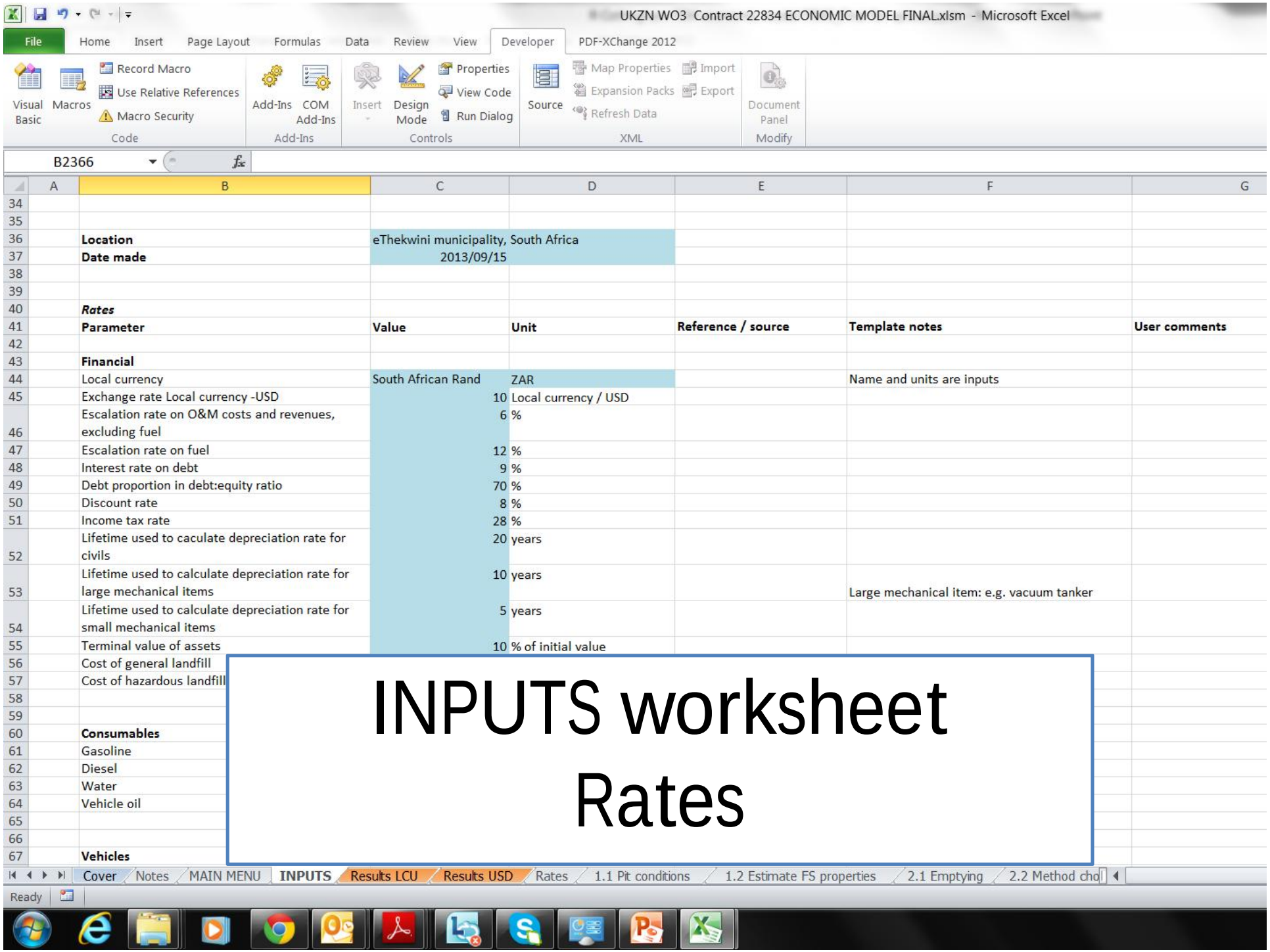
Export
XML
Document Panel
Modify
B2366
For model user:
INPUTS worksheet
7. List full references / bibliograph
8. The 'Template Notes' column gi
9. User comments provides space
Links to inputs for different mod
1. Pit conditions
2. Emptying
3. Conveyance
4. LaDePa Storage
5. LaDePa pre-treatment
6. LaDePa process
7. LaDePa product
8. LaDePa by-product
9. LaDePa cost calculations
13. Combustion process
14. Combustion product
15. Combustion by-product
16. Combustion cost calculations
18. Service provider costs
19. Product valuation
20. Crop application
Location
eThekwini municipality, South Africa
Date made
2013/09/15
Rates
Parameter
Value
Unit
Reference / source
Template notes
User comments
Financial
Local currency
South African Rand
ZAR
Name and units are inputs
Exchange rate Local currency -USD
10
Local currency / USD
Escalation rate on O&M costs and revenues, excluding fuel
6
%
Escalation rate on fuel
12
%
Interest rate on debt
9
%
Debt proportion in debt:equity ratio
70
%
Cover
Notes
MAIN MENU
INPUTS
Results LCU
Results USD
Rates
1.1 Pit conditions
1.2 Estimate FS properties
2.1 Emptying
2.2 Method cho
Ready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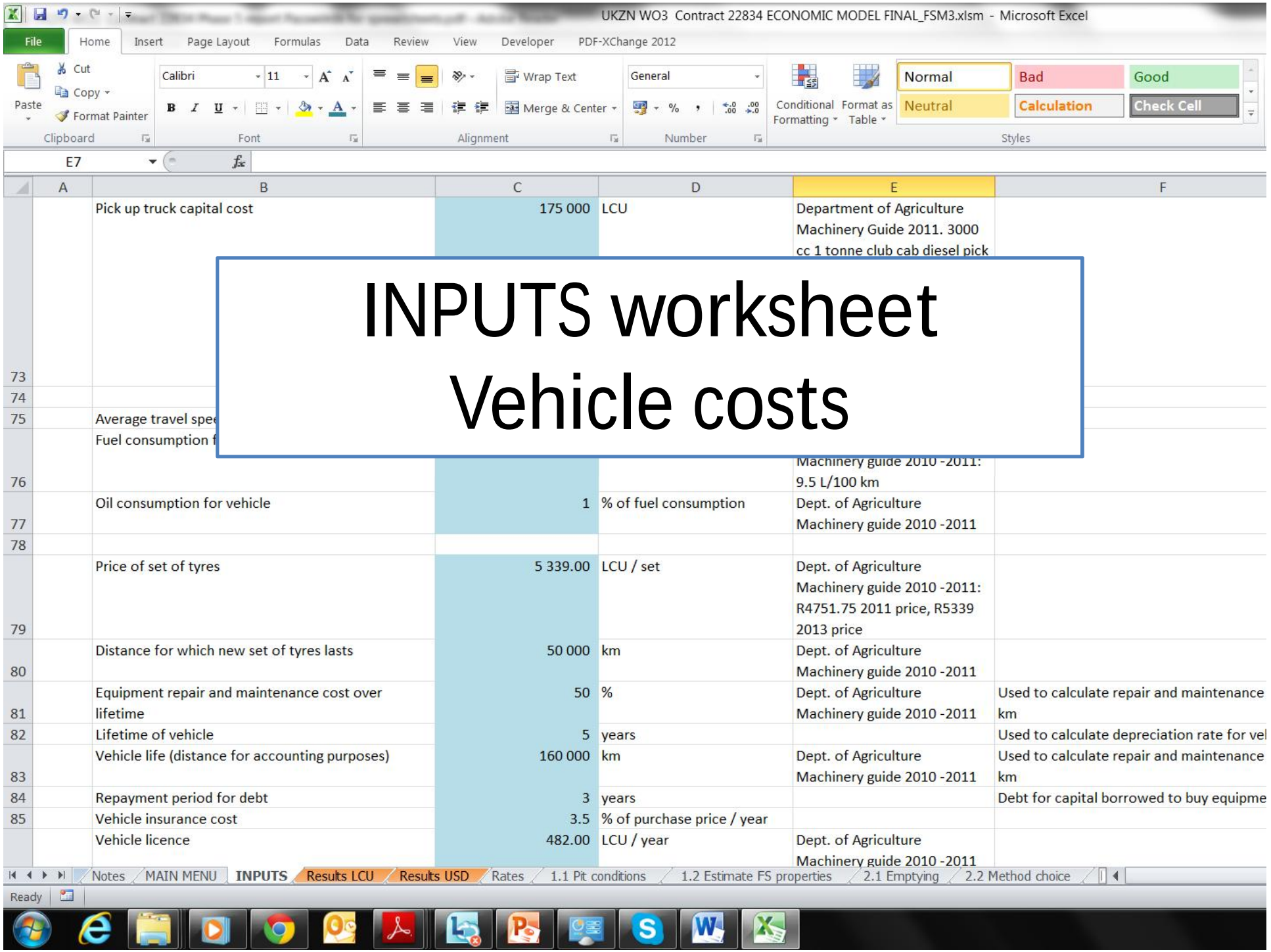
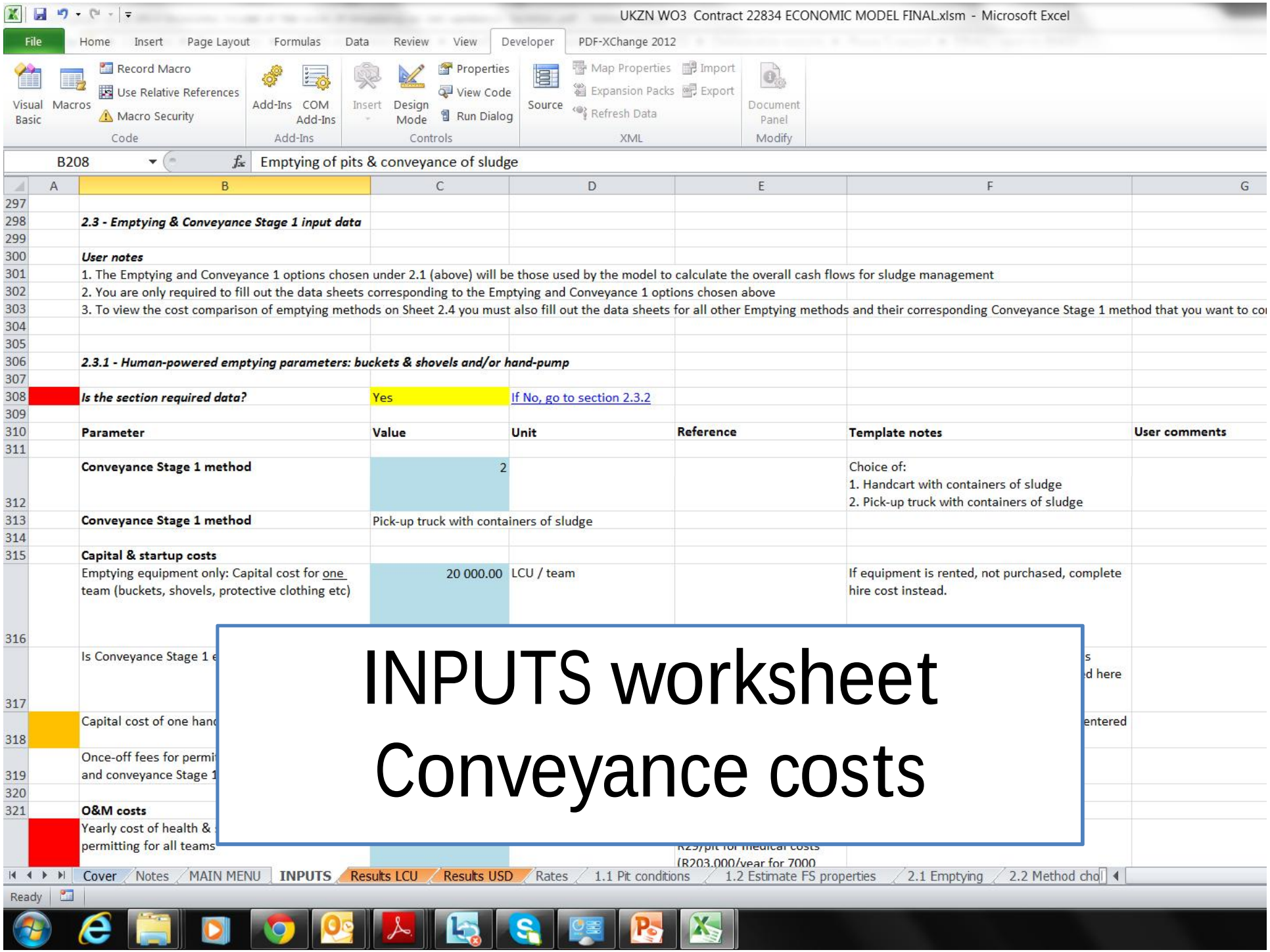
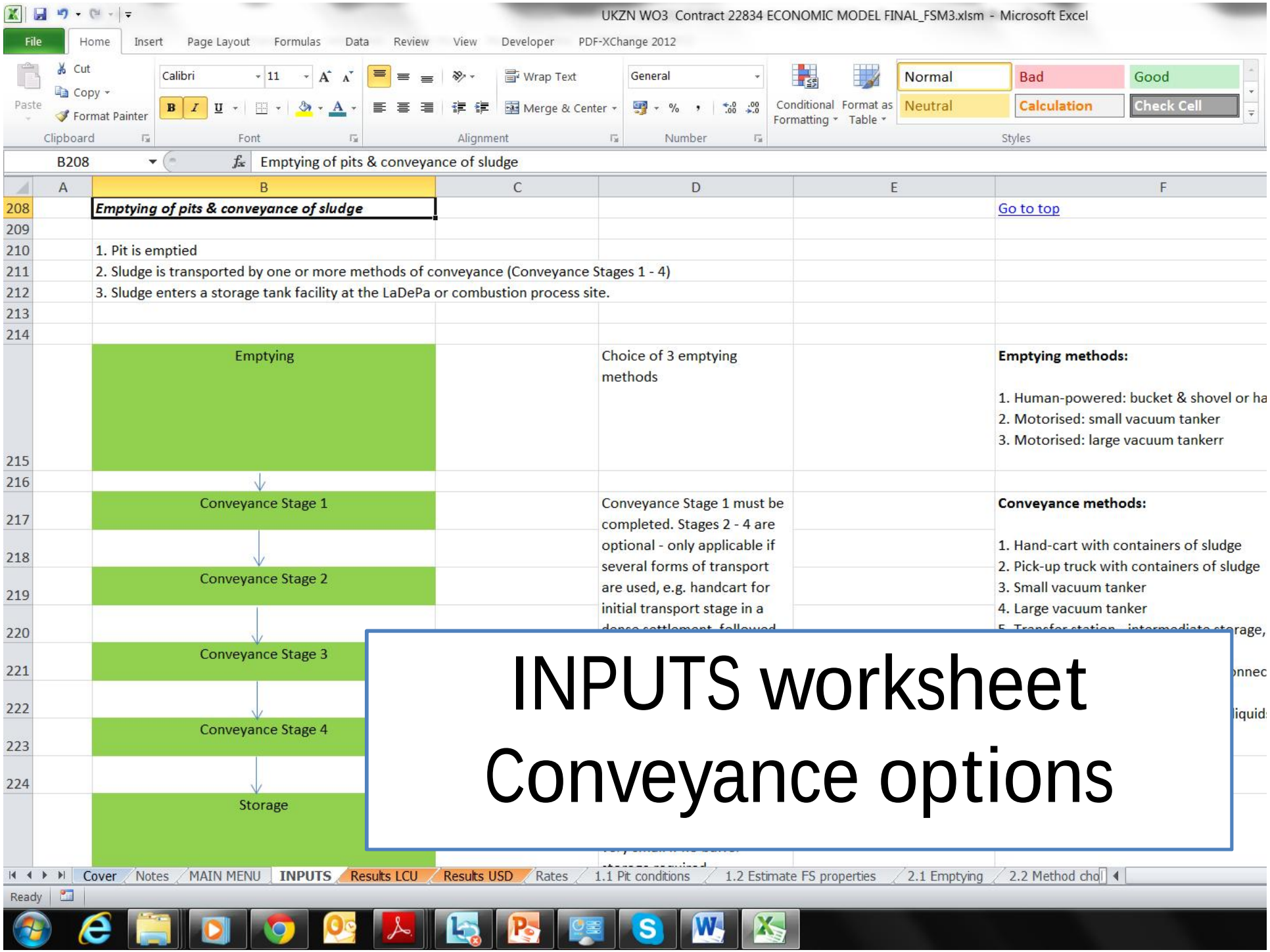
XML
Document Panel
Modify
B2366
Location
eThekwini municipality, South Africa
Date made
2013/09/15
Rates
Parameter
Value
Unit
Reference / source
Template notes
User comments
Financial
Local currency
South African Rand
ZAR
Name and units are inputs
Exchange rate Local currency -USD
10
Local currency / USD
Escalation rate on O&M costs and revenues, excluding fuel
6
%
Escalation rate on fuel
12
%
Interest rate on debt
9
%
Debt proportion in debt:equity ratio
70
%
Discount rate
8
%
Income tax rate
28
%
Lifetime used to caculate depreciation rate for civils
20
years
Lifetime used to calculate depreciation rate for large mechanical items
10
years
Large mechanical item: e.g. vacuum tanker
Lifetime used to calculate depreciation rate for small mechanical items
5
years
Terminal value of assets
10
% of initial value
Cost of general landfill
Cost of hazardous landfill
Consumables
Gasoline
Diesel
Water
Vehicle oil
Vehicles
INPUTS worksheet
Rates
Cover
Notes
MAIN MENU
INPUTS
Results LCU
Results USD
Rates
1.1 Pit conditions
1.2 Estimate FS properties
2.1 Emptying
2.2 Method cha
Ready



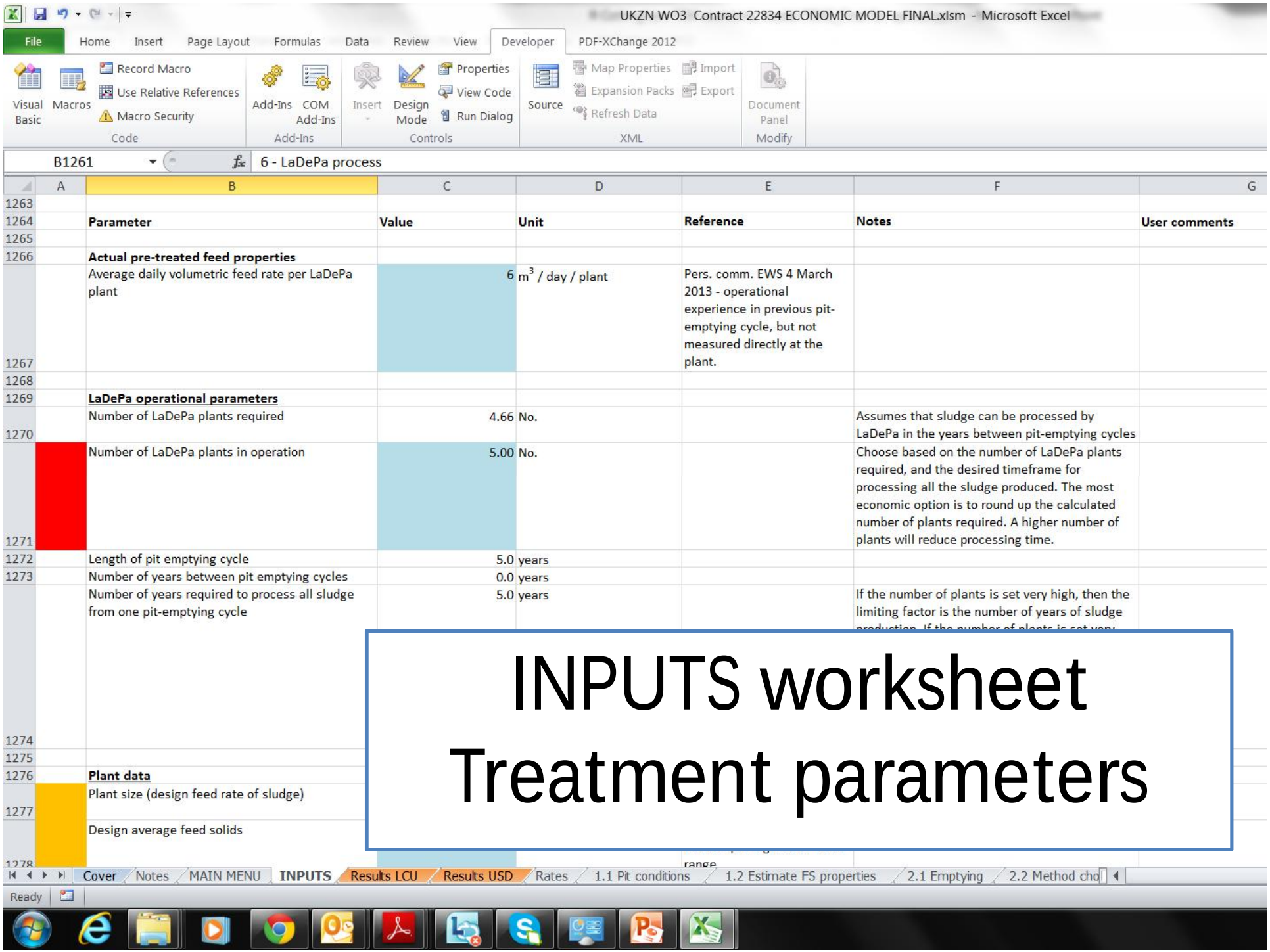
INPUTS worksheet
Vehicle costs



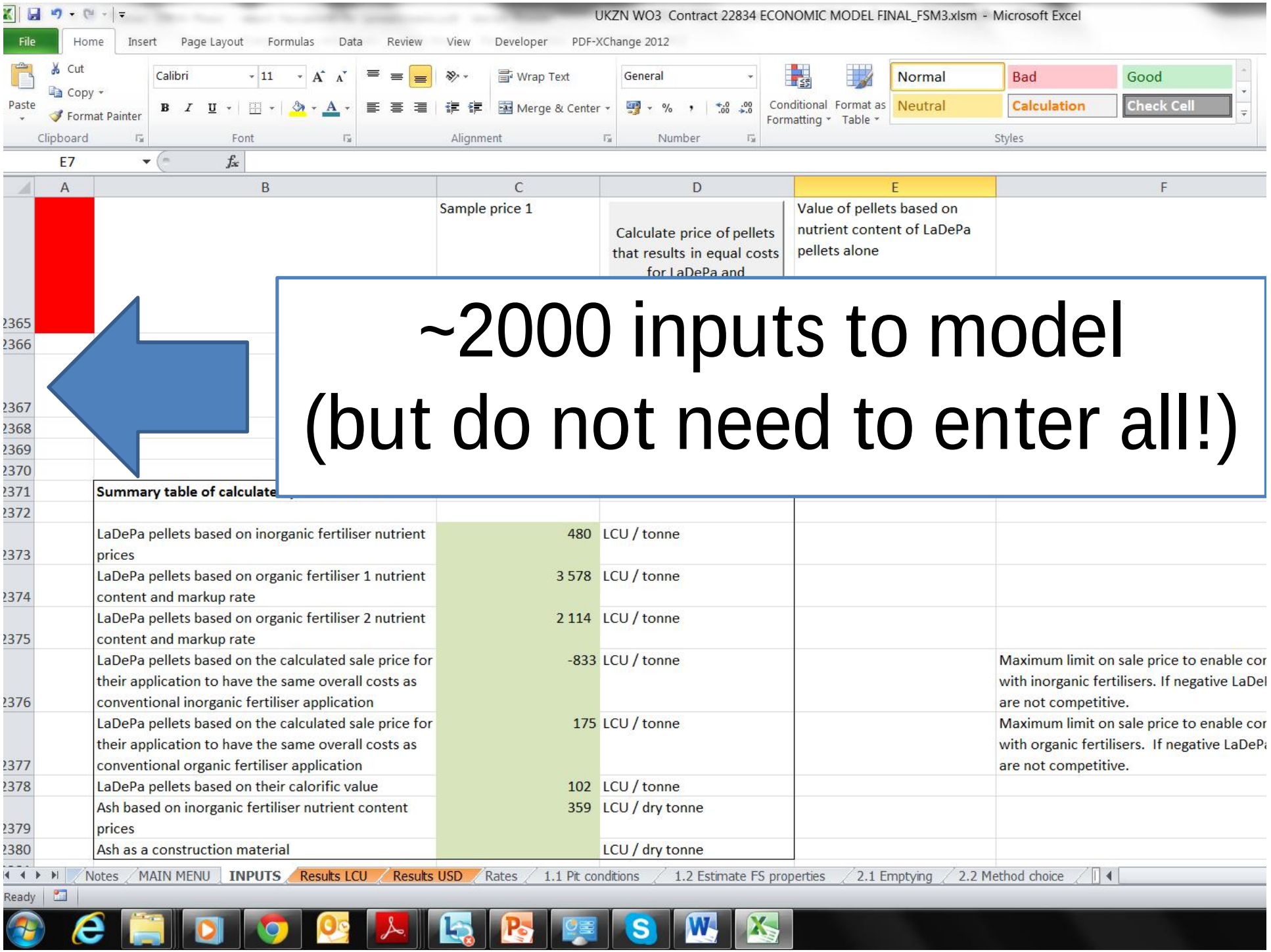
INPUTS worksheet
Conveyance costs



INPUTS worksheet
Conveyance options



INPUTS worksheet
Treatment parameters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Wrap Text
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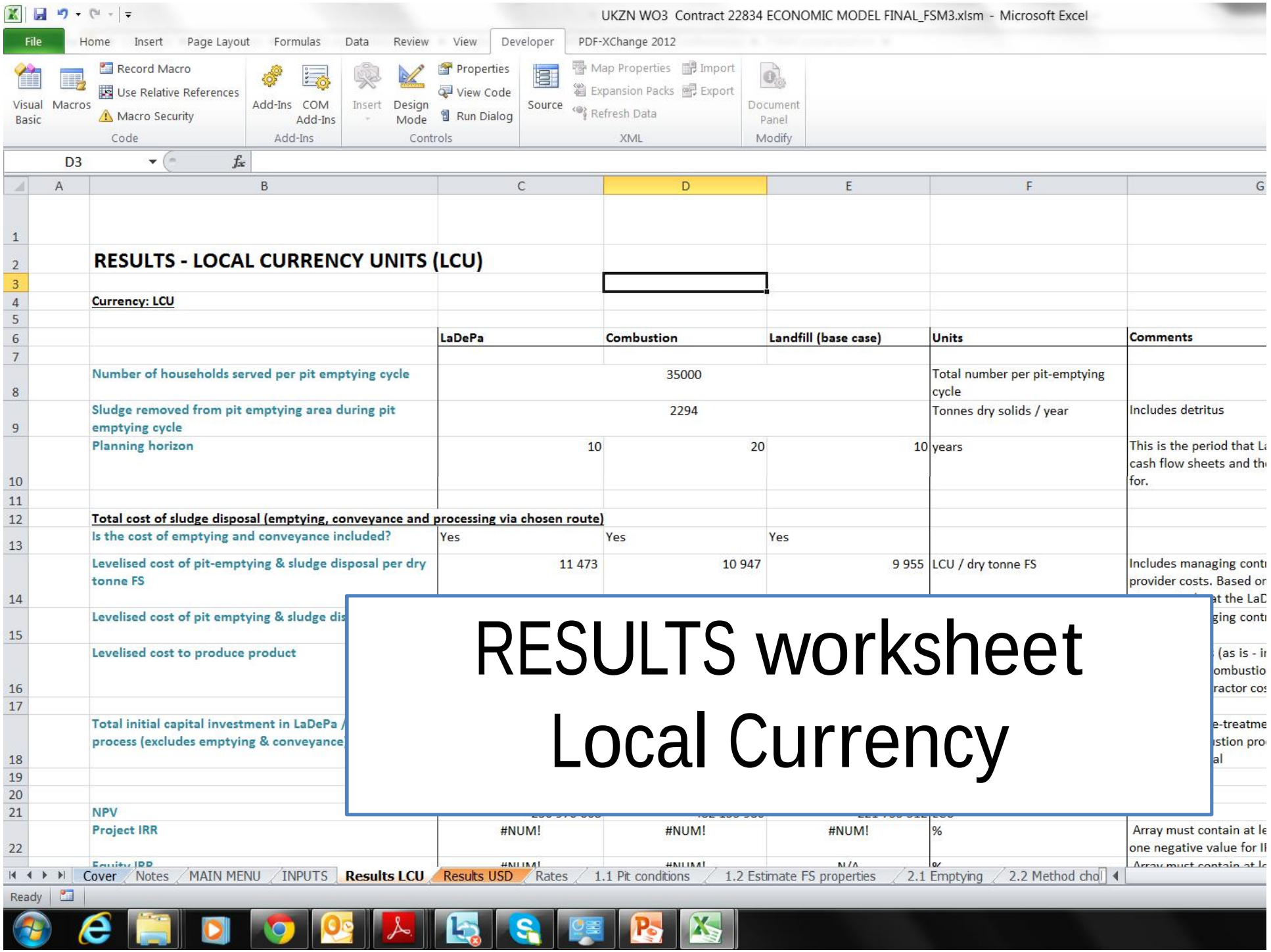
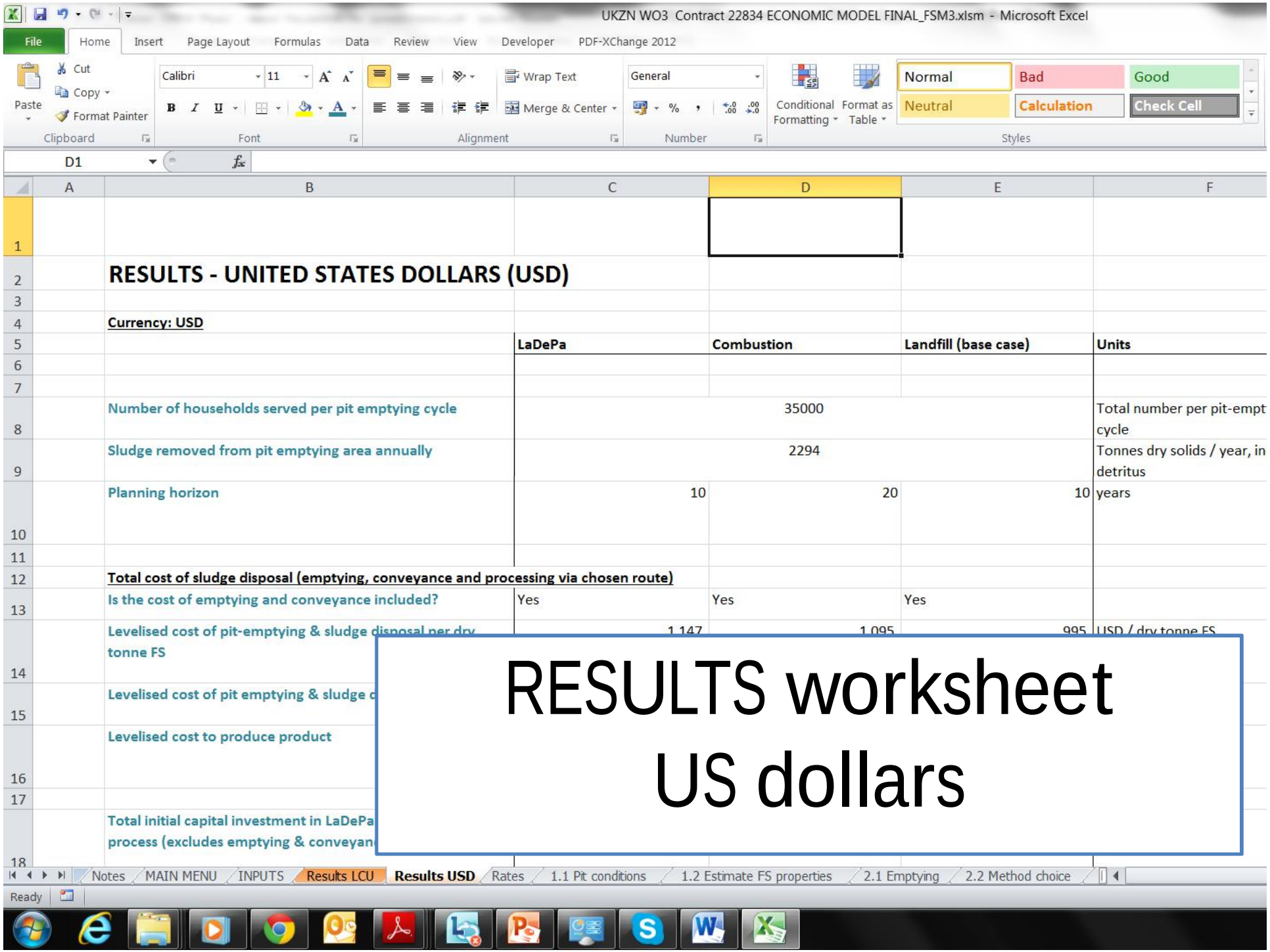
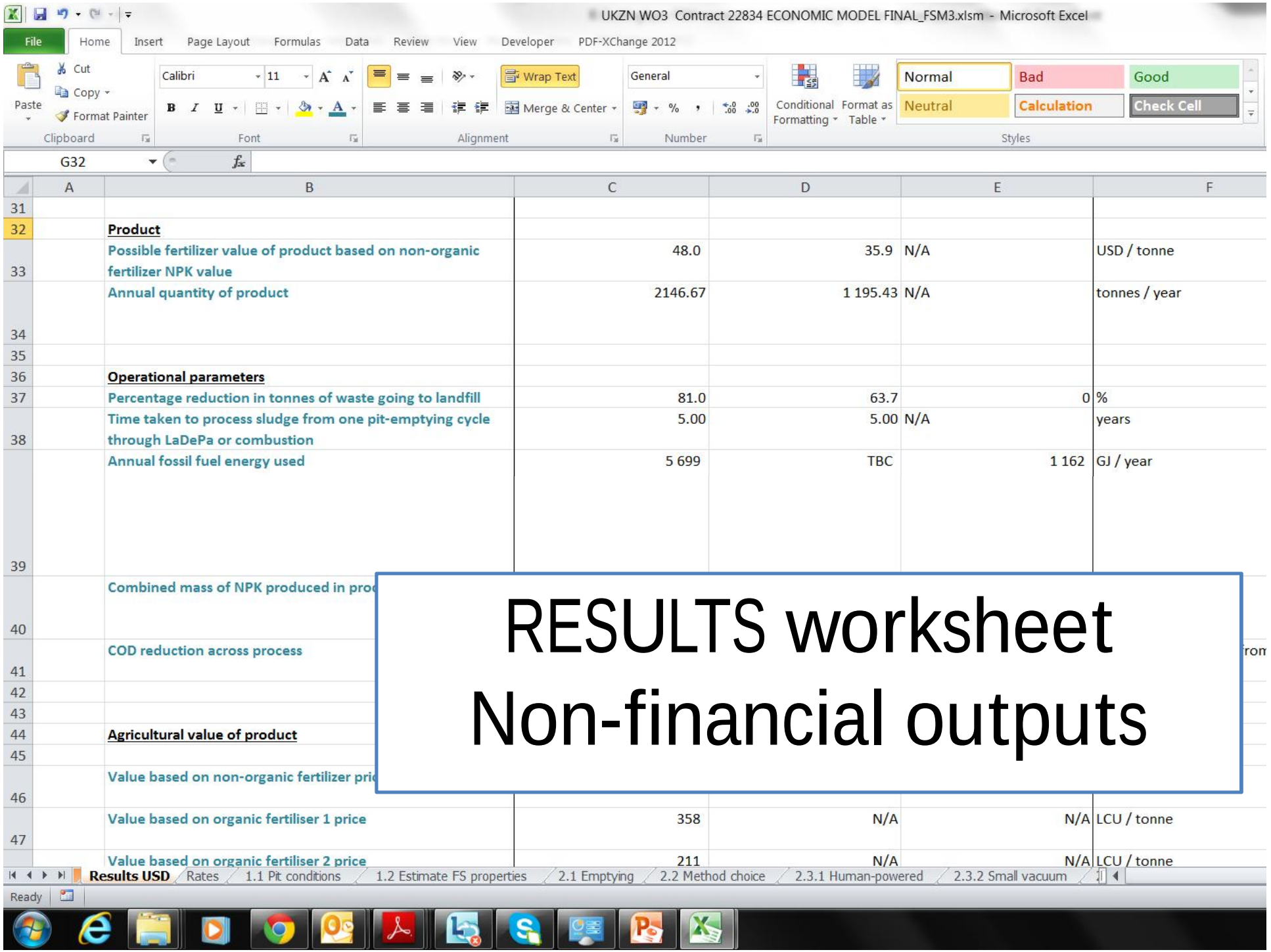
General
Number
Conditional Formatting
Format as Table
Normal
Bad
Good
Neutral
Calculation
Check Cell
Styles
E7
A
B
C
D
E
F
Sample price 1
Calculate price of pellets that results in equal costs for LaDePa and
Value of pellets based on nutrient content of LaDePa pellets alone
~2000 inputs to model
(but do not need to enter all!)
Summary table of calculate
LaDePa pellets based on inorganic fertiliser nutrient prices
480
LCU / tonne
LaDePa pellets based on organic fertiliser 1 nutrient content and markup rate
3 578
LCU / tonne
LaDePa pellets based on organic fertiliser 2 nutrient content and markup rate
2 114
LCU / tonne
LaDePa pellets based on the calculated sale price for their application to have the same overall costs as conventional inorganic fertiliser application
-833
LCU / tonne
Maximum limit on sale price to enable cor with inorganic fertilisers. If negative LaDeI are not competitive.
LaDePa pellets based on the calculated sale price for their application to have the same overall costs as conventional organic fertiliser application
175
LCU / tonne
Maximum limit on sale price to enable cor with organic fertilisers. If negative LaDeP are not competitive.
LaDePa pellets based on their calorific value
102
LCU / tonne
Ash based on inorganic fertiliser nutrient content prices
359
LCU / dry tonne
Ash as a construction material
LCU / dry tonne
Notes
MAIN MENU
INPUTS
Results LCU
Results USD
Rates
1.1 Pit conditions
1.2 Estimate FS properties
2.1 Emptying
2.2 Method choice
Ready



RESULTS worksheet
Local Currency

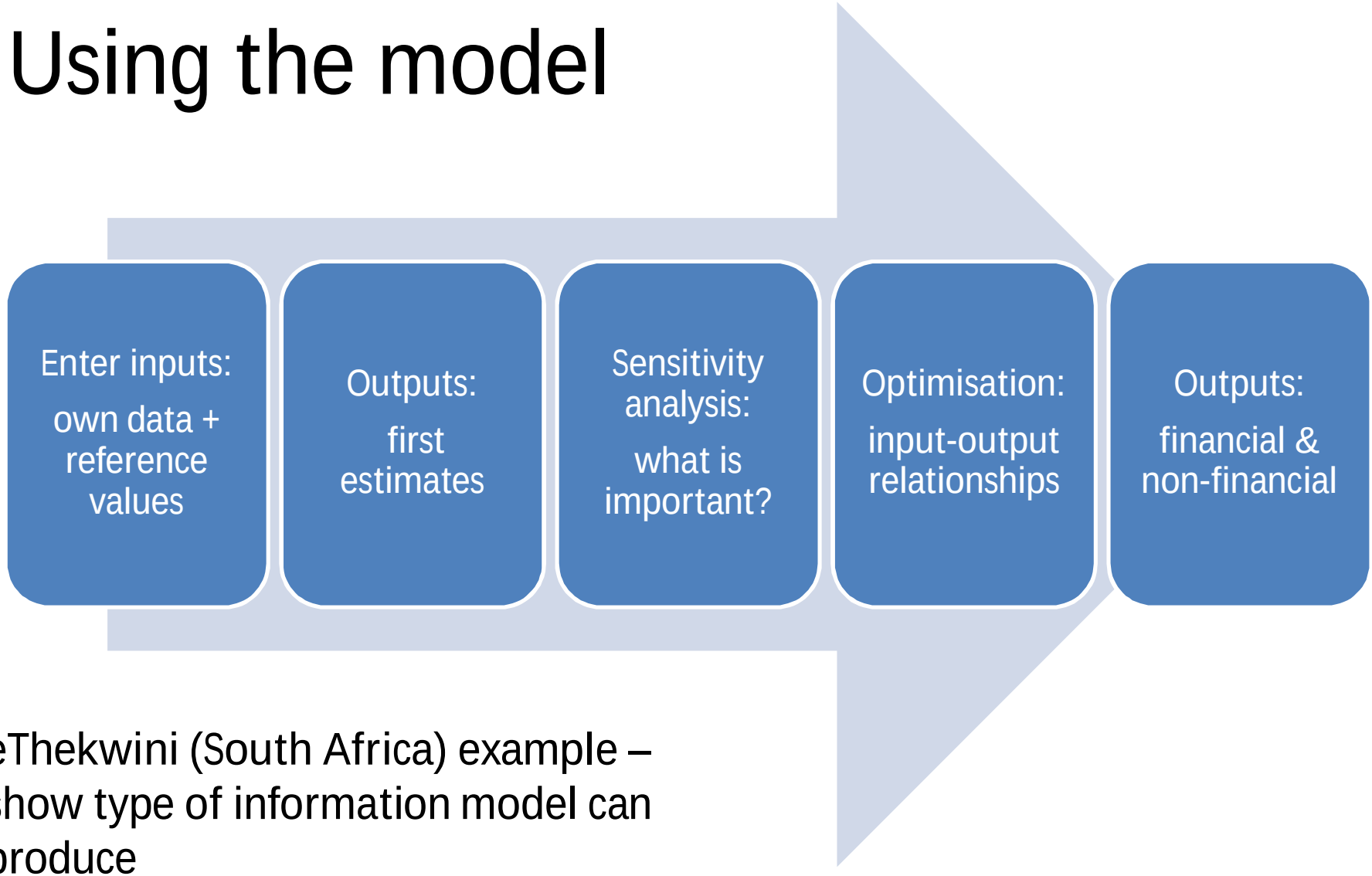


RESULTS worksheet
US dollars



RESULTS worksheet
Non-financial outputs

Using the model



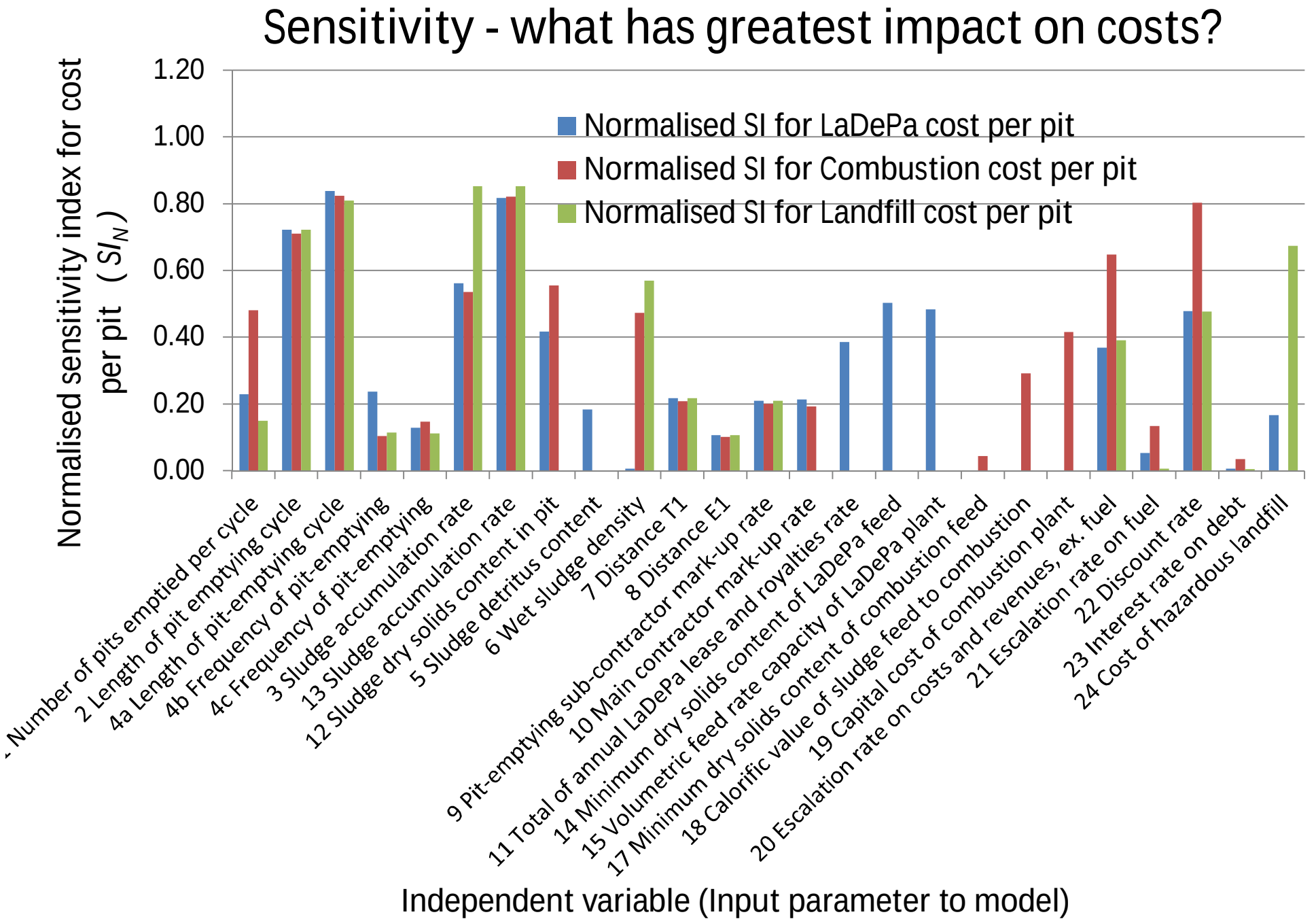
eThekwini (South Africa) example – show type of information model can produce

NOTE – Figures quoted are model case-specific, not generalised values!

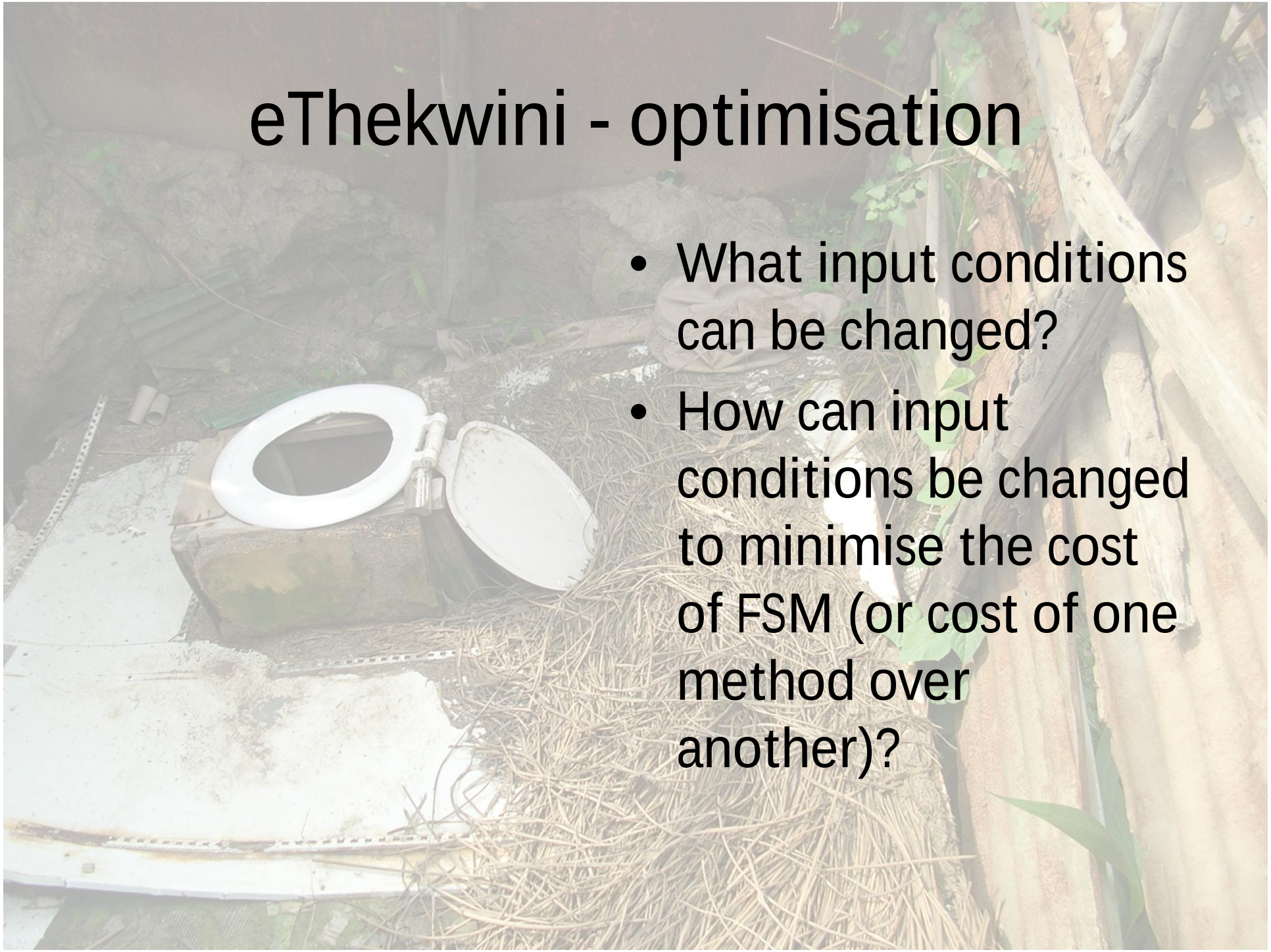
eThekwini first estimate outputs: LaDePa cost > incineration > landfill

Total cost of sludge disposal (emptying, conveyance and processing via chosen route)

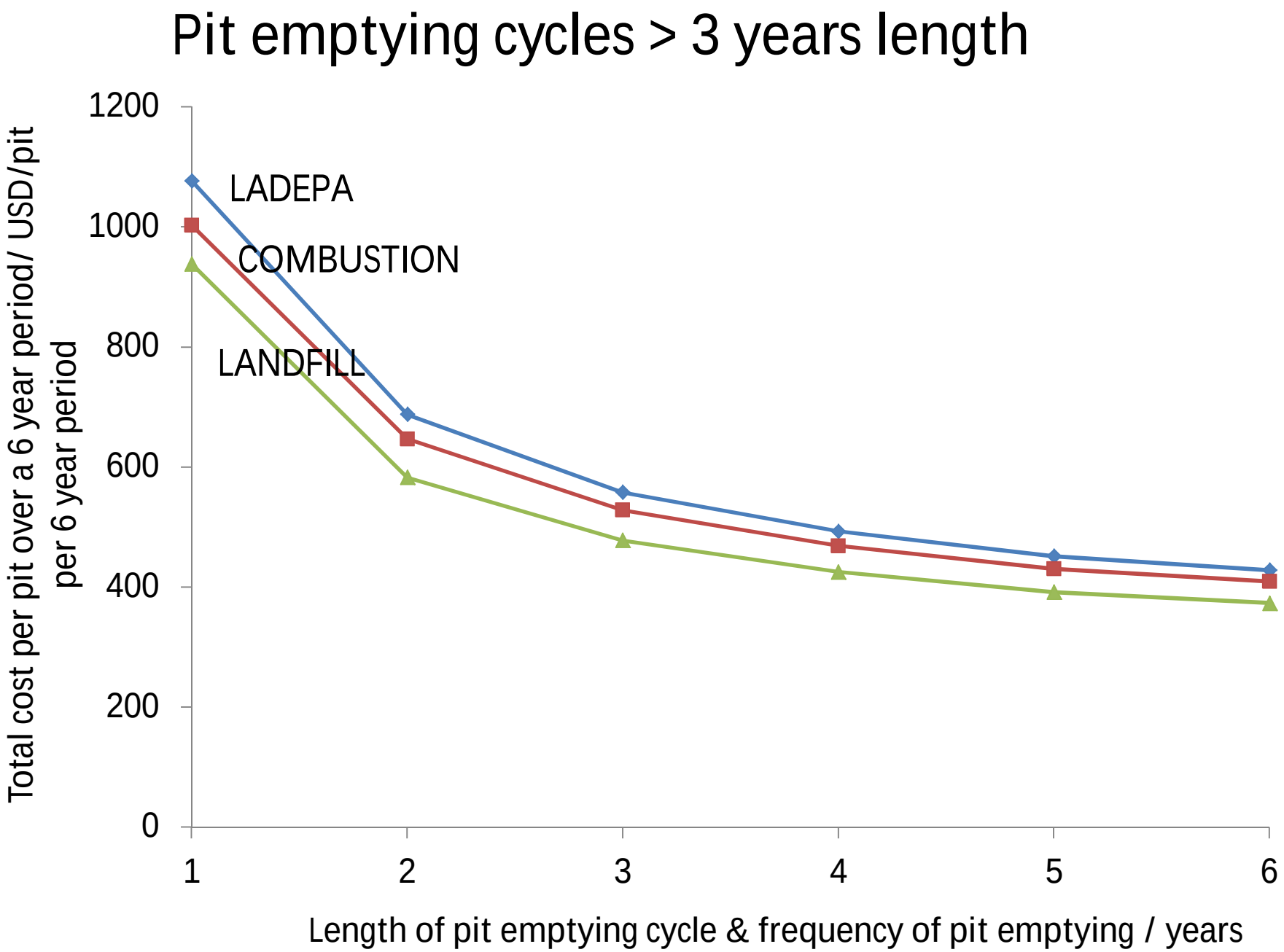
	LaDePa	Combustion	Landfill	
Levelised cost of pit-emptying & sludge disposal per dry tonne FS	1 150	1 100	1000	USD / dry tonne FS
Levelised cost of pit emptying & sludge disposal per pit	380	360	330	USD / pit
Levelised cost to produce product	1 230	2 100	N/A	USD / tonne product

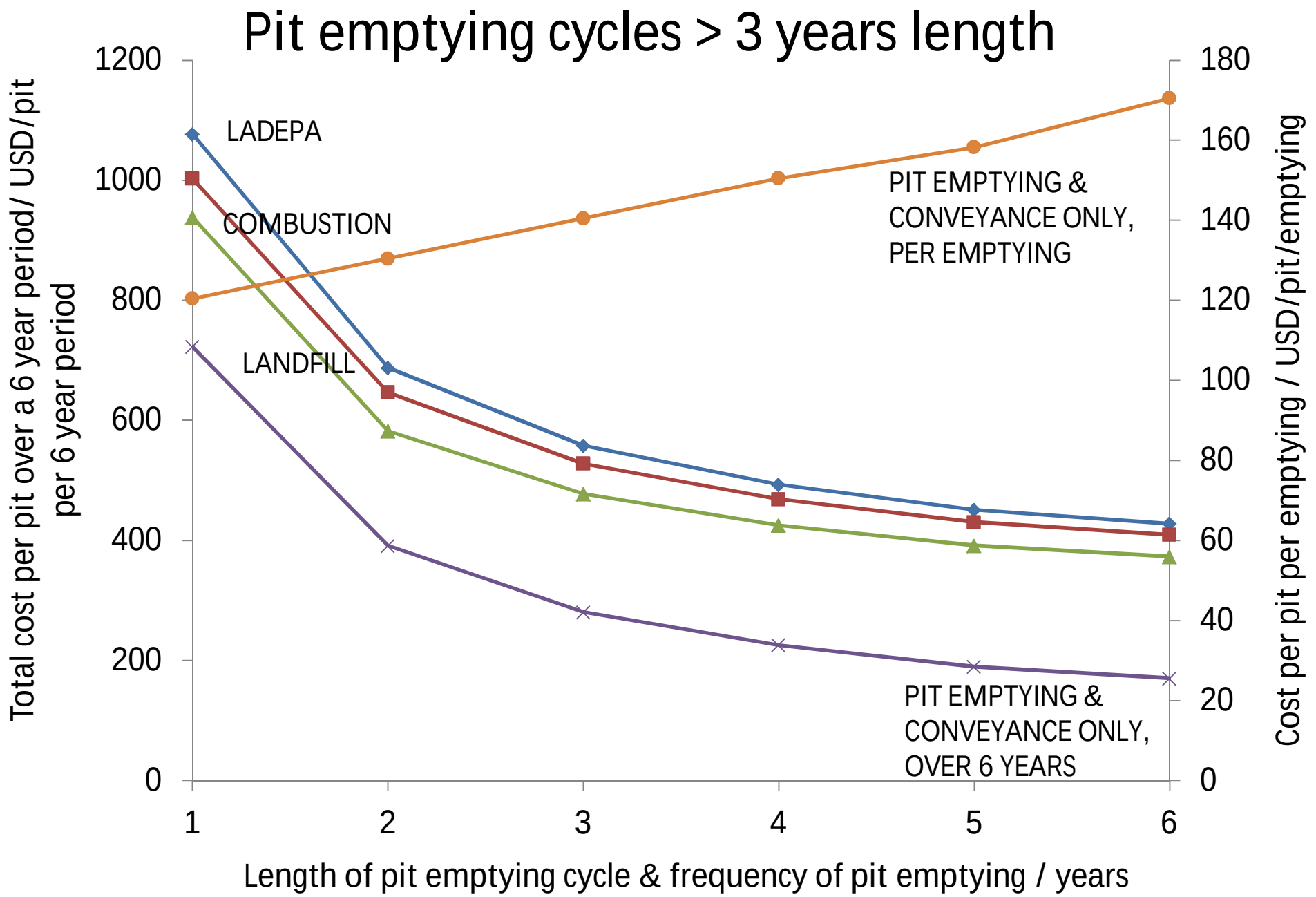

Sensitivity - what has greatest impact on costs?
Normalised sensitivity index for cost per pit (SI_N)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Normalised SI for LaDePa cost per pit
Normalised SI for Combustion cost per pit
Normalised SI for Landfill cost per pit
1 Number of pits emptied per cycle
2 Length of pit emptying cycle
4a Length of pit-emptying cycle
4b Frequency of pit-emptying
4c Frequency of pit-emptying
3 Sludge accumulation rate
13 Sludge accumulation rate
12 Sludge dry solids content in pit
5 Sludge detritus content
6 Wet sludge density
7 Distance T1
8 Distance E1
9 Pit-emptying sub-contractor mark-up rate
10 Main contractor mark-up rate
11 Total of annual LaDePa lease and royalties rate
14 Minimum dry solids content of LaDePa feed
15 Volumetric feed rate capacity of LaDePa plant
17 Minimum dry solids content of combustion feed
18 Calorific value of sludge feed to combustion
19 Capital cost of combustion plant
20 Escalation rate on costs and revenues, ex. fuel
21 Escalation rate on fuel
22 Discount rate
23 Interest rate on debt
24 Cost of hazardous landfill
Independent variable (Input parameter to model)

eThekwini - optimisation

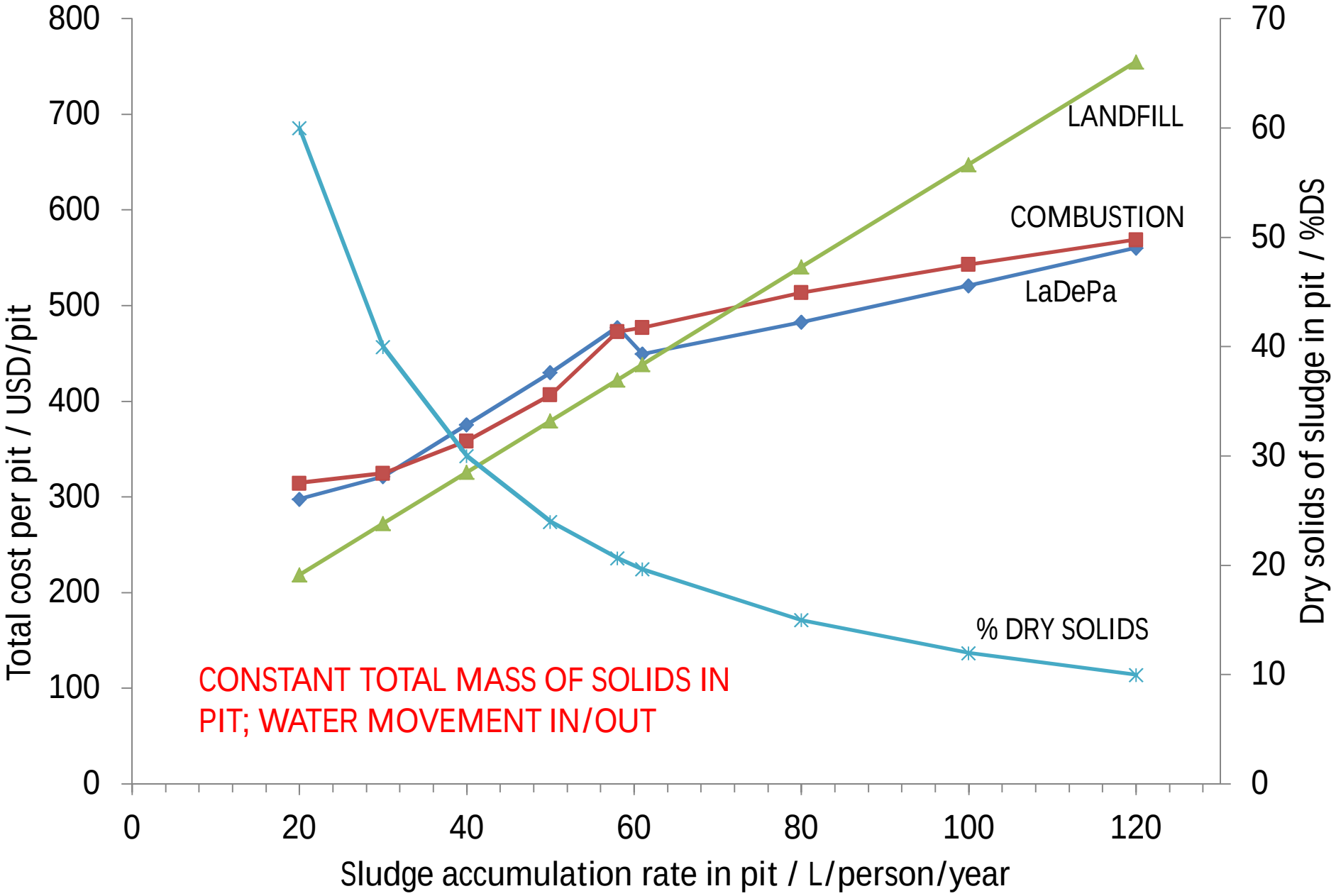


- What input conditions can be changed?
- How can input conditions be changed to minimise the cost of FSM (or cost of one method over another)?


Pit emptying cycles > 3 years length
Total cost per pit over a 6 year period/ USD/pit per 6 year period
1200
1000
800
600
400
200
0
LADEPA
COMBUSTION
LANDFILL
1
2
3
4
5
6
Length of pit emptying cycle & frequency of pit emptying / years

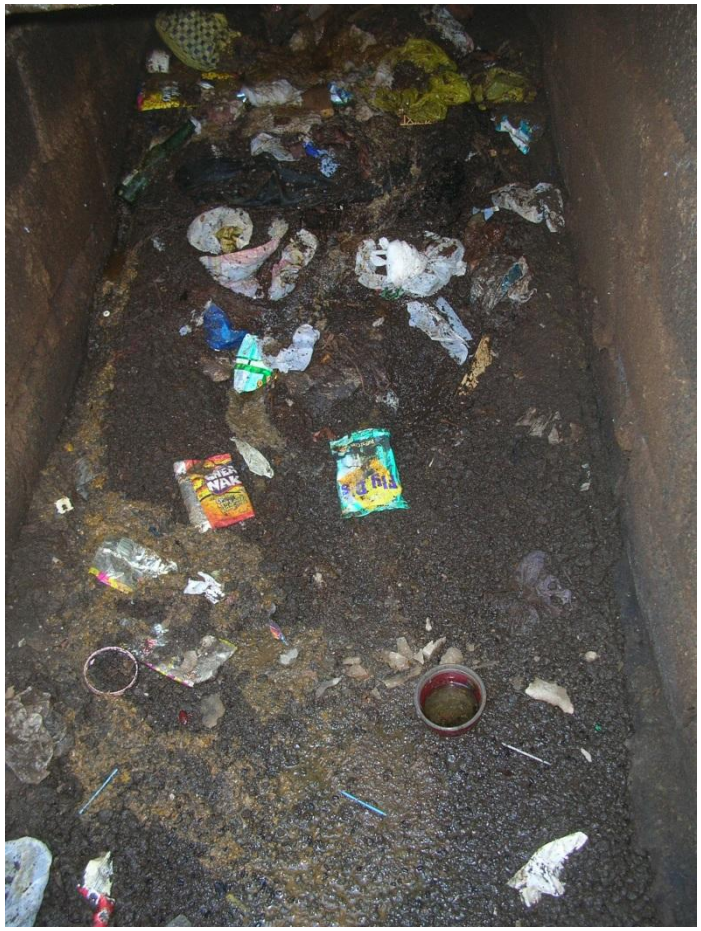

Pit emptying cycles > 3 years length
Total cost per pit over a 6 year period/ USD/pit per 6 year period
Cost per pit per emptying / USD/pit/emptying
Length of pit emptying cycle & frequency of pit emptying / years
LADEPA
COMBUSTION
LANDFILL
PIT EMPTYING & CONVEYANCE ONLY, PER EMPTYING
PIT EMPTYING & CONVEYANCE ONLY, OVER 6 YEARS
0
200
400
600
800
1000
1200
0
20
40
60
80
100
120
140
160
180
1
2
3
4
5
6

Produce drier sludge in pits



eThekwini – minimising cost of FSM

- Maximise no. of households included
- Longer pit emptying cycles
- Minimise sludge accumulation rates
  - Solid waste; pit drainage
- Match %DS required for treatment to %DS obtained in raw sludge
- Optimise decentralisation of treatment plants



Endproduct values – how significant?

- Product valuation: Partial Budget Analysis
- For a specific crop, soil & distance to market, what price makes a sludge end-product competitive with a conventional fertiliser?
  - NPK content
  - Distance to market
  - Fertiliser application costs
- Increasing endproduct value by changes to FSM chain

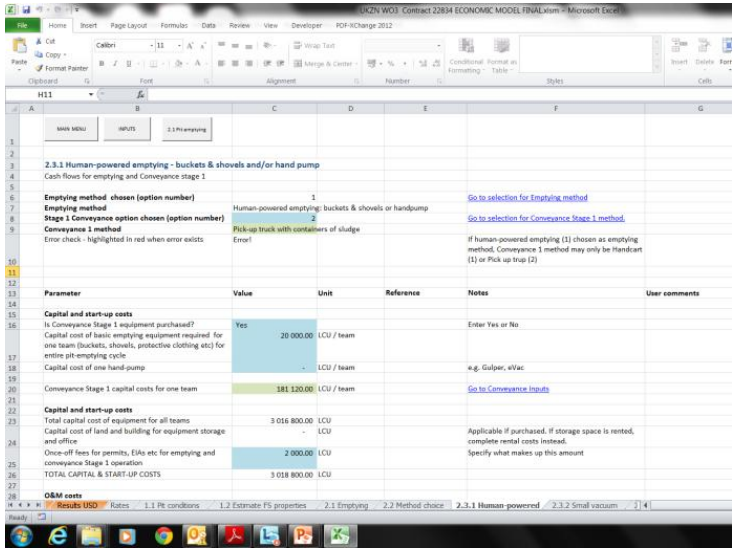
Limitations & future work

- Improve input data:
  - Sludge, LaDePa pellet & ash properties
  - LaDePa & combustion operational data
  - Other locations
- User interface


LaDePa plant

- Refine the model:
  - Predicting endproduct composition & value from feed sludge data
  - Monetising micro-nutrient & carbon benefits
  - Develop combustion module; energy recovery
  - Determine optimal conditions for LaDePa & combustion
  - Value of ash - construction material
- Link to other FSM models

Project outputs



- Spreadsheet model
- Report:
  - Guide to using the model
  - Application to eThekwini
- FSM data sets
  - Durban, South Africa: majority dry pits
  - Dakar, Senegal: majority septic tanks

- All available for use

rscottingham@cantab.net

http://prg.ukzn.ac.za

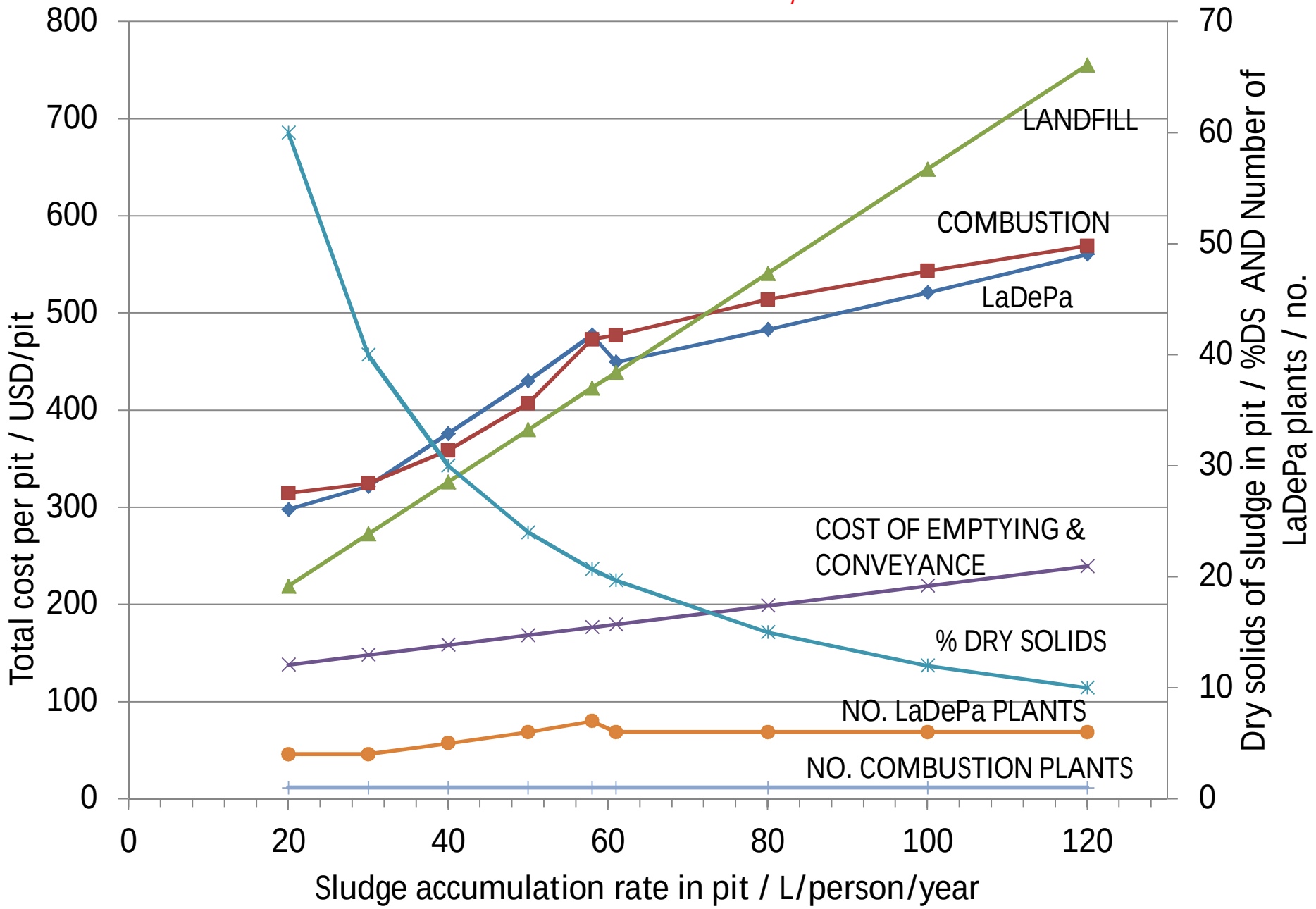
Acknowledgements

- Bill & Melinda Gates Foundation
- Sub-grantees
  - Partners in Development: Dave Still
  - SANDEC/EAWAG: Linda Strande
- Université Cheikh Anta Diop de Dakar, Senegal: EM Sonko
- eThekwini Water & Sanitation: Dave Wilson, John Harrison, Teddy Gounden
- UKZN Department of Crop Science: Alfred Odindo
- UKZN School of Life Sciences: Nicola Rodda, Colleen Archer
- Coal & Waste Utilisation: Jason Germanis
- Fertiliser Society of South Africa: Adam Mostert
- Cedara: Dr Luiz Pereira

Supplementary slides

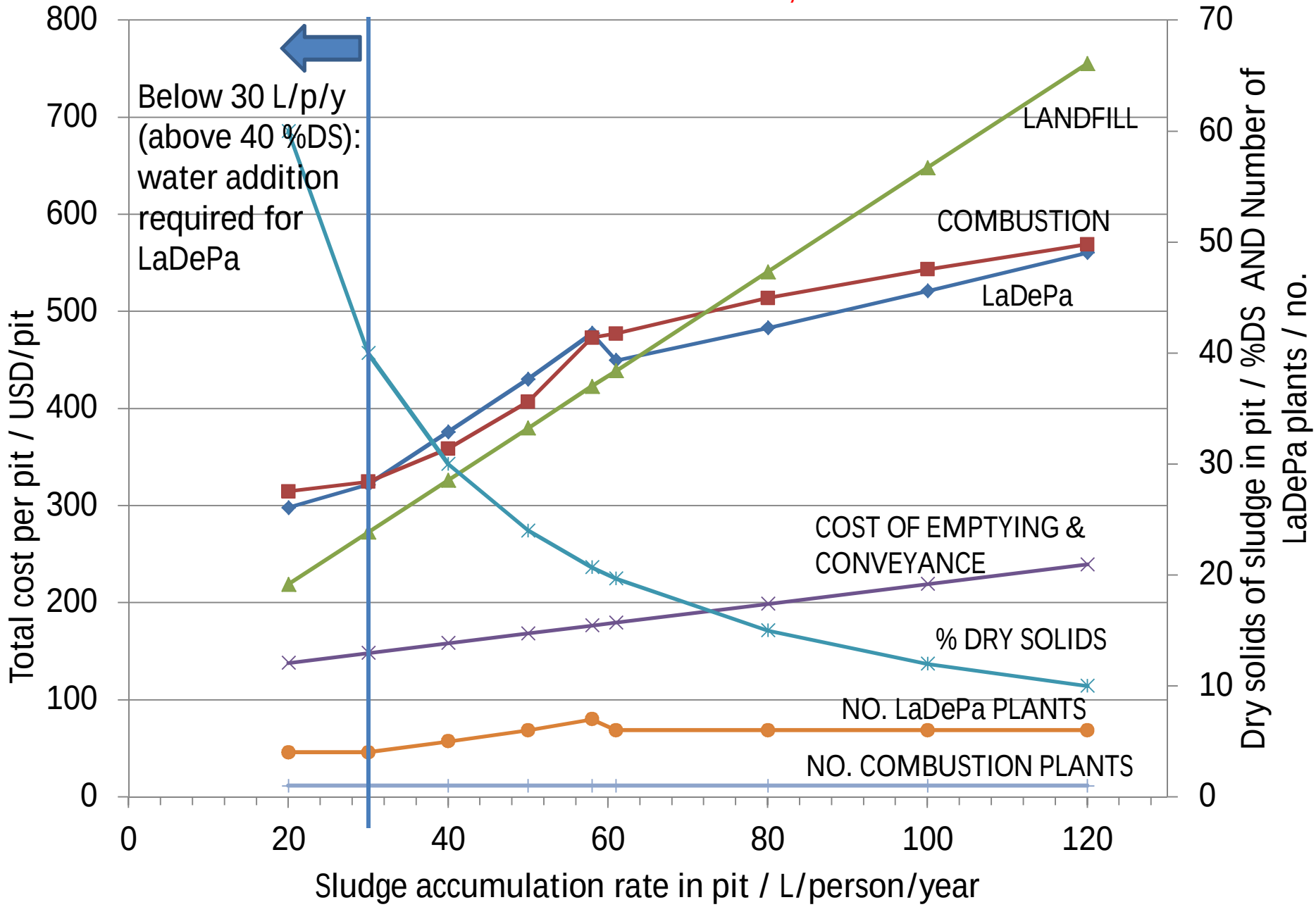
Produce drier sludge in pits

CONSTANT TOTAL MASS OF SOLIDS IN PIT; WATER MOVEMENT IN/OUT



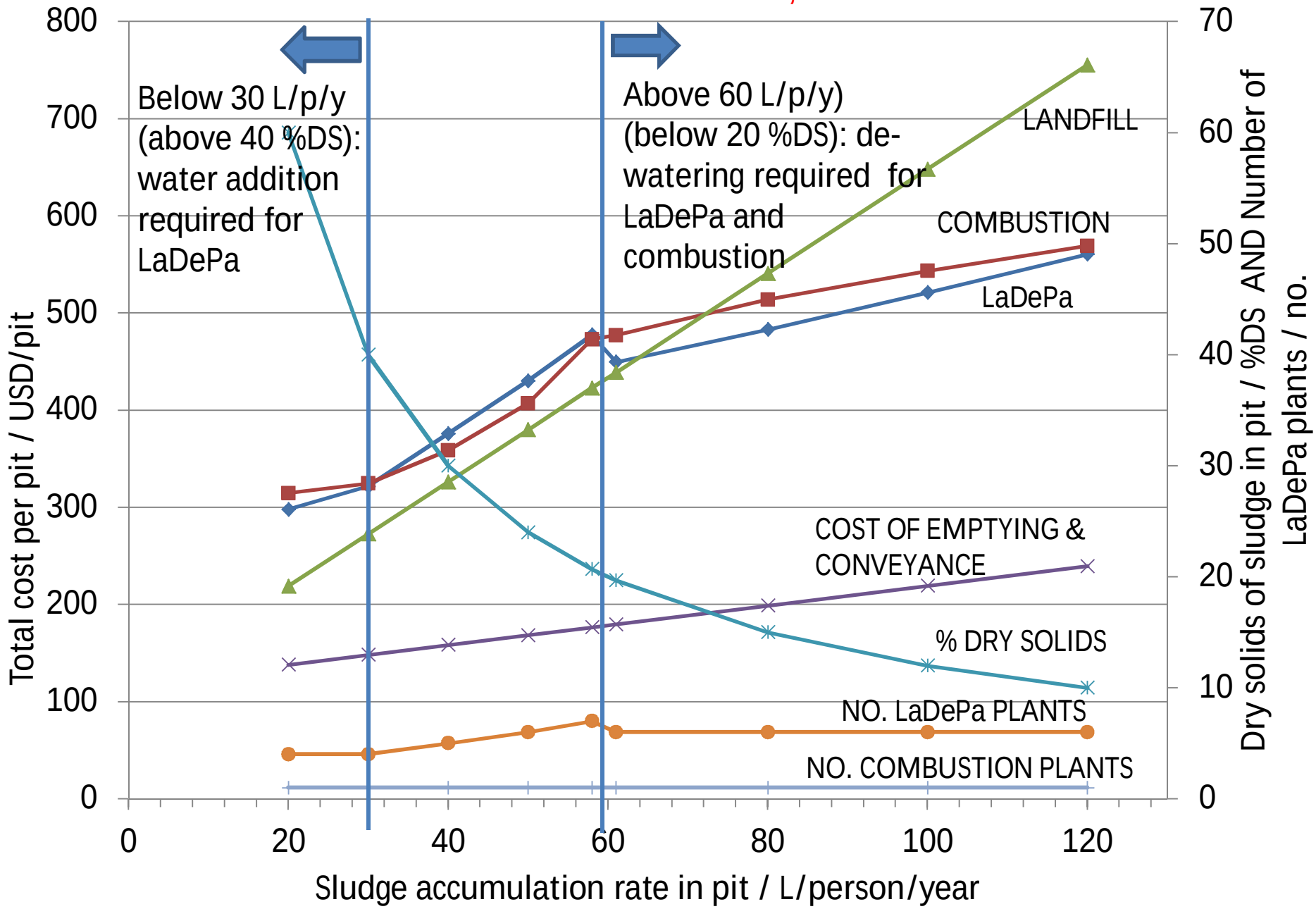
Produce drier sludge in pits

CONSTANT TOTAL MASS OF SOLIDS IN PIT; WATER MOVEMENT IN/OUT

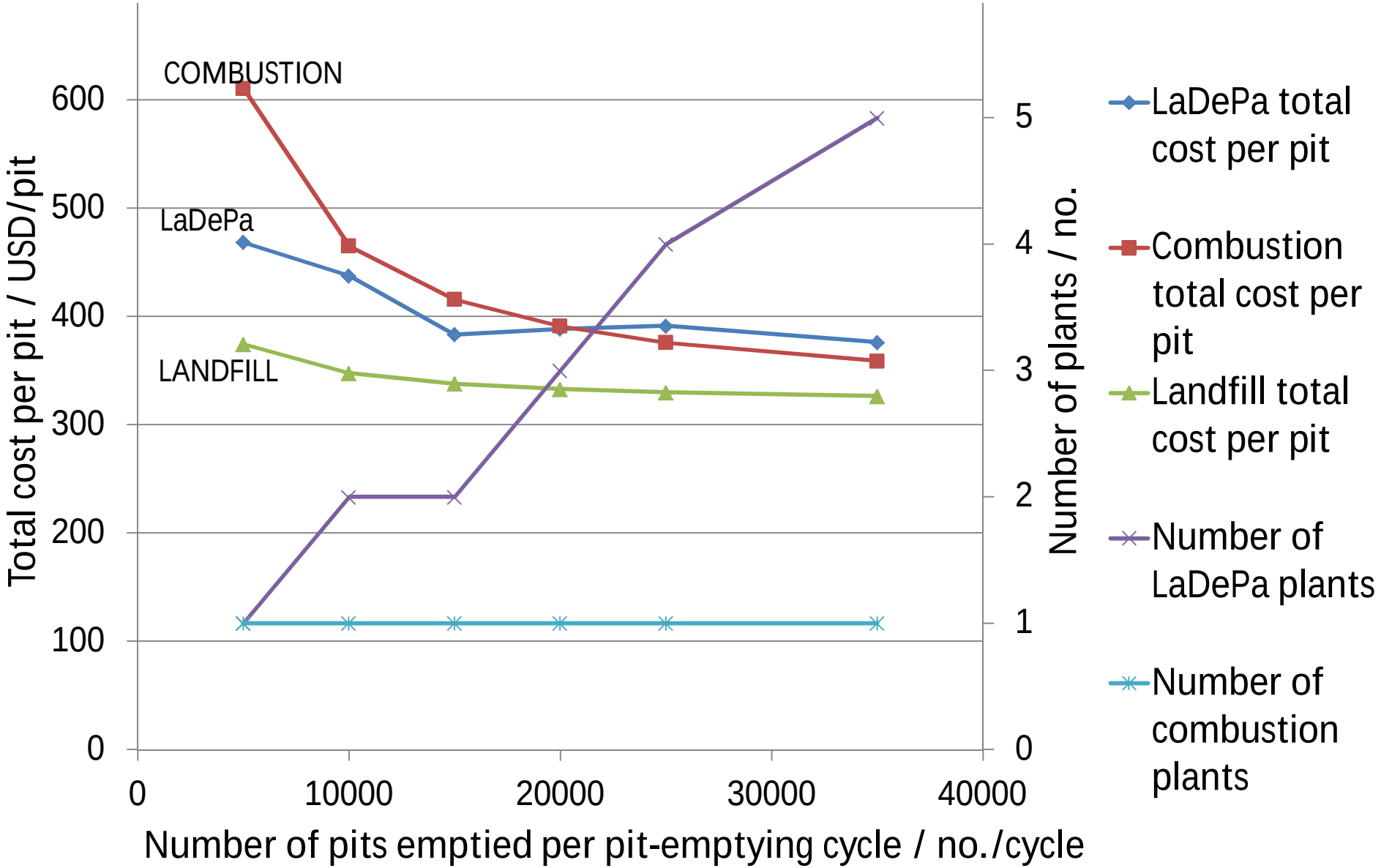


Produce drier sludge in pits

CONSTANT TOTAL MASS OF SOLIDS IN PIT; WATER MOVEMENT IN/OUT



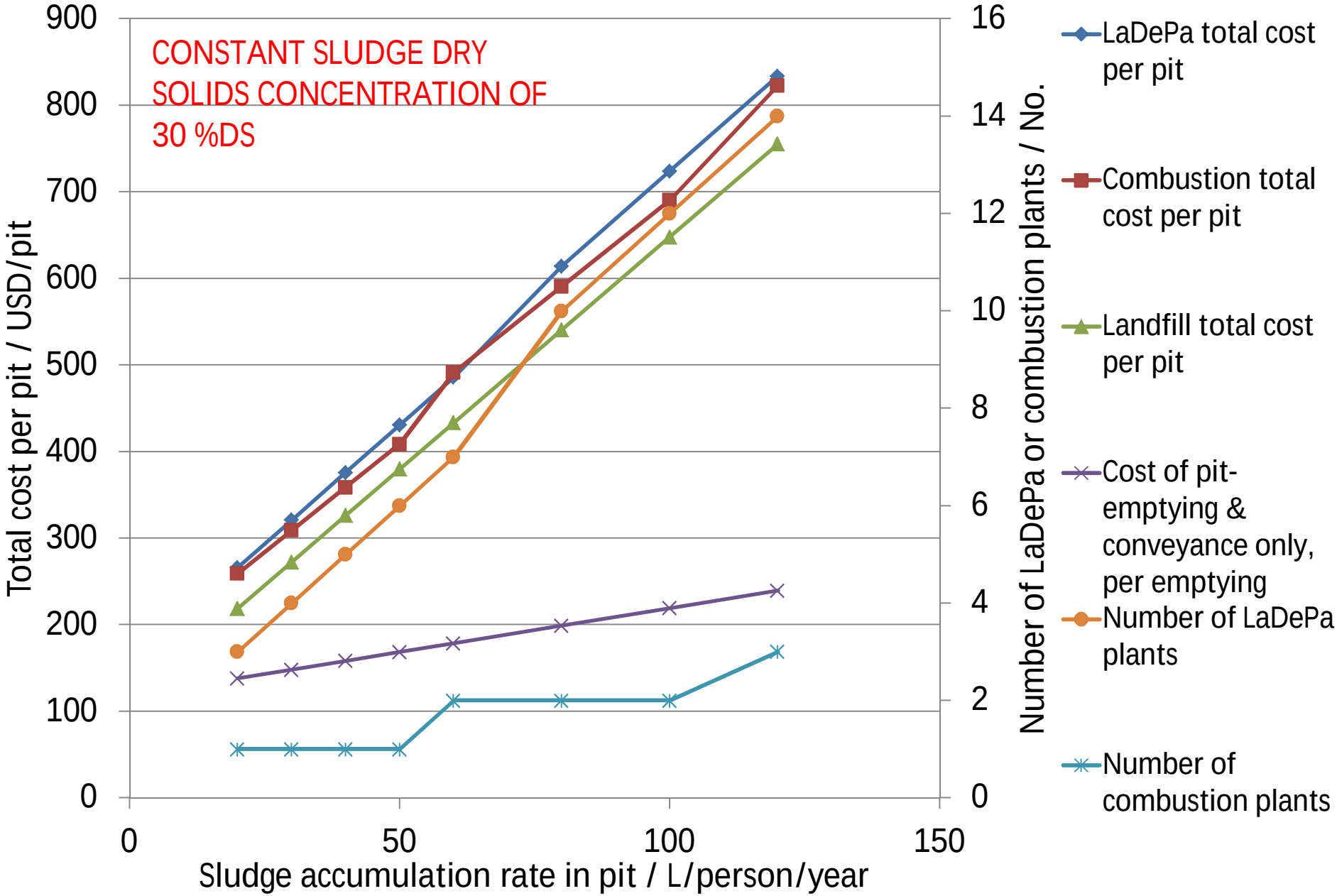
Maximise the number of pits emptied



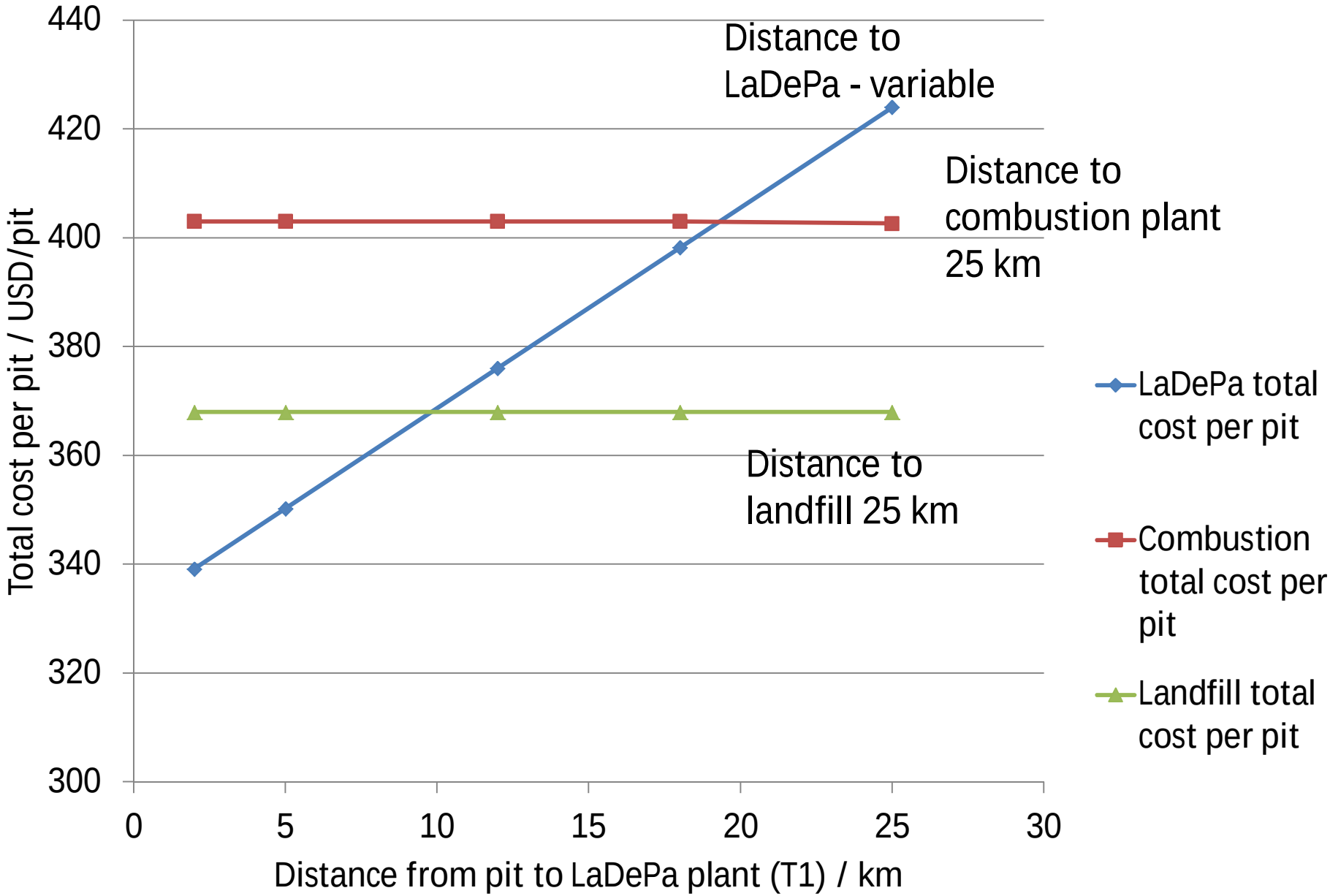
Produce less sludge per pit

(e.g. better solid waste collection)

VARIABLE TOTAL MASS OF SOLIDS IN PIT IN PROPORTION TO ACC. RATE



Decentralise effectively – mobile LaDePa plants



Calculation of SI_N

- SI_I = (I_max – I_min) / I_max
- SI_D = (D_max – D_min) / D_max
- SI_N = SI_D / SI_I

EWS business model